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Vol. 4

ORIGINAL

Pilot Program: NRC Severe Reactor Accident Incident Response Training Manual

Public Protective Actions — Predetermined Criteria and Initial Actions

U.S. Nuclear Regulatory Commission

Office of Inspection and Enforcement

J. A. Martin, Jr., T. J. McKenna, C. W. Miller, L. M. Hively, R. W. Sharpe, J. G. Giitter, R. M. Watkins

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Public Protective Actions — Predetermined Criteria and Initial Actions

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A

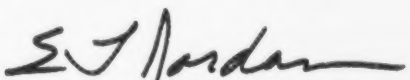
FOREWORD

Over the past few years the Office of Inspection and Enforcement (IE), Division of Emergency Preparedness and Engineering Response, has undertaken a program to upgrade the NRC capabilities to respond to severe reactor accidents. As part of this effort, basic training sessions have been presented by IE staff to all response personnel (Headquarters and regions). Through the process of providing this training a standard student text has evolved.

This pilot training manual has been written to fill the need for a general text on NRC response to reactor accidents. The manual is intended to be the foundation for a course for all NRC response personnel.

This set of manuals is not licensing guidance. Rather, it is designed to present to NRC personnel the best understanding of response planning for a serious reactor accident.

These draft manuals are intended to change over time as NRC staff continues to gain experience. Suggestions are requested and should be sent to the Incident Response Branch.



Edward L. Jordan, Director
Division of Emergency Preparedness
and Engineering Response
Office of Inspection and Enforcement

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PREFACE

Public Protective Actions--Predetermined Criteria and Initial Actions is the fourth in a series of volumes that collectively summarize the U.S. Nuclear Regulatory Commission (NRC) emergency resonse during severe power reactor accidents and provide necessary background information. This volume reviews public protective action criteria and objectives, their bases and implementation, and the expected public response. Other volumes in the series are:

* Volume 1 -- Overview and Summary of Major Points

* Volume 2 -- Severe Reactor Accident Overview

* Volume 3 -- Response of Licensee and State and Local Officials

* Volume 5 -- U.S. Nuclear Regulatory Commission Response

Each volume serves, respectively, as the text for a course of instruction in a series of courses for NRC response personnel. These materials do not provide guidance or license requirements for NRC licensees. The volumes have been organized into these training modules to accommodate the scheduling and duty needs of participating NRC staff. Each volume is accompanied by an appendix of slides that can be used to present this material. The slides are called out in the text.

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LIST OF ACRONYMS AND INITIALISMS FOR VOLUMES 1-5

ALARA	As low as reasonably achievable
AMS	Aerial Measurements System(s)
ARAC	Atmospheric Release Advisory Capability
ASC	Administrative Support Coordinator
AST	Administrative Support Team
BT	Base Team (NRC Regional Office)
BWR	Boiling Water Reactor
CDPA	Civil Defense Preparedness Agency
CFA	Cognizant Federal Agency
CFR	Code of Federal Regulations
CL	Congressional Liaison
CRD	Control rod drive
CRDHS	Control rod drive hydraulic system
CSF	Critical Safety Function
DBA	Design Basis Accident
DOC	Department of Commerce, U.S.
DOD	Department of Defense, U.S.
DOE	Department of Energy, U.S.
DOI	Department of Interior, U.S.
DOT	Department of Transportation, U.S.
DSO	Director of Site Operations
EAL	Emergency Action Level
ECCS	Emergency Core Cooling System
EDO	Executive Director of Operations
ENS	Emergency Notification System
EO	Emergency Officer
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedure
EPA	Environmental Protection Agency, U.S.
EPRI	Electrical Power Research Institute
EPZ	Emergency Planning Zone
ERC	Emergency Response Coordinator
ERM	Emergency Response Manager
ERO	Emergency Response Organization
ERT	Emergency Response Team (FEMA organization)
ESF	Engineered Safety Feature
EST	Emergency Support Team (FEMA organization)
ET	NRC Executive Team
ETA	Estimated time of arrival
FBI	Federal Bureau of Investigation
FDA	Food and Drug Administration, U.S.
FEMA	Federal Emergency Management Agency
FRC	Federal Response Center
FRERP	Federal Radiological Emergency Response Plan
FRMAC	Federal Radiological Monitoring and Assessment Center
FRMAP	Federal Radiological Monitoring and Assessment Plan
FTS	Federal Telephone System
GLC	Government Liaison Coordinator

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GLM	Government Liaison Manager
GLO	Government Liaison Officer
GLT	Government Liaison Team
HHS	Health and Human Services, U.S. Department of
HOO	NRC Headquarters Operations Officer
HPCI	High-pressure coolant injection
HPCS	High-pressure core spray
HPN	Health Physics Network
HQ	NRC Headquarters
HUD	Housing and Urban Development, U.S. Department of
IE	NRC Office of Inspection and Enforcement
ICRP	International Commission on Radiological Protection
IDAS	Interactive Dose Assessment System
IRB	Incidence Response Branch
IRC	Regional NRC Incident Response Center
IRDAM	Interactive Rapid Dose Assessment Model
JIC	Joint Information Center
LC	Liaison Coordinator
LNO	Liaison Officer
LOCA	Loss of Coolant Accident
LPCI	Low-pressure coolant injection
LPCS	Low-pressure core spray
LT	Liaison Team
LWR	Light Water Reactor
NCS	National Communication System
NMSS	NRC Office of Nuclear Material Safety and Safeguards
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission, U.S.
NRR	NRC Office of Nuclear Reactor Regulation
NWS	National Weather Service
OC	Operations Center
OSC	Operations Support Center (site)
PA	Public Affairs
PAC	Public Affairs Coordinator
PAG	Protective Action Guides
PAM	Public Affairs Manager
PAR	Protective Action Recommendation
PASS	Post-accident Sampling Systems
PAT	Public Affairs Team
PMC	Protective Measures Coordinator
PMM	Protective Measures Manager
PMT	Protective Measures Team
P-T	Pressure-Temperature
PWR	Pressurized Water Reactor
RA	Regional Administrator
RAT	Radiological Assistance Team
RBE	Relative biological effectiveness
RCIC	Reactor core isolation cooling
RCT	Response Coordination Team
RDO	Regional Duty Officer
R.G.	Regulatory Guide
RHR	Residual heat removal
RI	Resident Inspector

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RM	Resource Manager
RO	NRC Regional Office
RSC	Reactor Safety Coordinator
RSM	Reactor Safety Manager
RST	Reactor Safety Team
SC	Safeguards/Security Coordinator
SFO	Senior FEMA Official
SGC	Safeguards/Security Coordinator
SGT	Safeguards Team
SI	International System (of measurement)
SLC	Standby liquid control
SM	Safeguards/Security Manager
SO	Status Officer
ST	Site Team
STL	Site Team Leader
TLD	Thermoluminescent dosimeter
TMI-2	Three Mile Island--Unit 2
TSC	Technical Support Center
USDA	U.S. Department of Agriculture
WHO	World Health Organization

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1. OBJECTIVES

Slides 1 and 2

Following completion of this section, the student should be able to

- describe the contributions to dose by various pathways of exposure,
- describe the basic radiation protection objectives for emergency response,
- describe the initial protective actions warranted for severe core damage accidents,
- describe the role and efficacy of other protective actions,
- describe the relationship of protective action guides (PAGs) and emergency action levels (EALs),
- describe the Nuclear Regulatory Commission (NRC) severe accident protective guidance and its basis,
- describe why evacuation recommendations should <u>not be delayed for fear of panic</u>, and
- describe NRC's role in the early implementation of predetermined protective actions.

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2. FUNDAMENTAL PUBLIC PROTECTIVE ACTION OBJECTIVES

2.1 NATURE OF THE THREAT

Slides 3 and 4

In many ways, the risk from a radioactive plume is similar to that from any hazardous cloud. The population should avoid being immersed in the hazardous cloud, breathing from the hazardous cloud, and entering areas contaminated by the cloud's passage. Obviously, the major difference is that a plume released as a result of a major reactor accident will be radioactive and not hazardous in other ways (e.g., flammable, corrosive).

Generally, a major release from a nuclear power plant can be viewed as a cloud (called the plume) of radioactive gases, aerosol particles (smoke), and water vapor (mist). The plume could be very hot and rise as it leaves the plant (e.g., as steam rises), as was the case for the Chernobyl accident. If this is the case, the population close to the plant may be spared many of the consequences as the plume passes overhead. The plume could be released continuously over a long period, or it could be released as a very short puff. As the radioactive plume (cloud) moves away from the reactor site, radioactive particles or aerosols will settle out (on the ground, trees, people, etc.). This is called ground contamination.

Slide 5

As explained in Vol. 2, the radiation received by a person is called "dose." A person can receive a dose from a plume in three ways, usually called pathways. First, dose can be received externally from the radiation given off by the passing plume or the deposited contamination. This type of dose is called cloud or ground shine.

Dose can also be received from actually contacting a plume (e.g., by inhaling the radioactive material in the plume; this is called the inhalation dose). Inhaled material, in addition to directly providing a dose, contains certain elements that

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concentrate in particular organs (e.g., lungs or thyroid) and thus become a special threat to those organs. Contact with a plume can also result in contamination of a person (clothing, skin).

Finally, dose can be received from eating or drinking contaminated food or water. This is called the ingestion dose. As in the case of inhaled material, ingested material can concentrate in various organs.

Slide 6

The two organs that receive special attention in protective action considerations are the whole body and the thyroid. Sufficiently high doses to the whole body are considered to be fatal, so whole body dose levels are used to estimate early deaths and injuries. Whole body dose is received as a result of shine from the passing plume, shine from ground contamination caused by the passing plume, and inhalation of the plume.

Thyroid dose is important because inhalation or ingestion of small amounts of radioiodine can result in damage or destruction of the thyroid. However, unlike whole body dose, the dose to the thyroid will not be fatal in most cases.

Milk always receives special attention because radioactive iodine and cesium can be concentrated in the milk of cows that eat contaminated food or grass. The iodine in the milk can then be further concentrated in the consumer's thyroid.

2.2 BASIC RADIATION PROTECTION OBJECTIVES

Slide 7

Any protective actions taken in response to a severe nuclear accident should have the following objectives:

1. to <u>avoid</u> (prevent) doses sufficient to cause early severe health effects (injuries or deaths) that would be seen at whole body doses above 100 rem;

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2. to reduce doses above those limits established by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Health and Human Services (HHS) Food and Drug Administration (FDA) protective action guides; and

3. to control total long-term effects (e.g., total cancers).

These objectives do not share equal status. They are listed in decreasing order of importance. Even within the first objective, one must distinguish between early fatality (death within about 60 days) and other less serious injuries [e.g., vomiting, malaise, and thyroid ablation (complete loss of function)].

Obviously, the first protective actions should be directed toward meeting the first objective by keeping the whole body dose from the passing plume (shine and inhalation) and resulting ground contamination below levels that could result in early deaths or injuries.

Slide 8

The Environmental Protection Agency and Food and Drug Administration protective action guides pertain to the second of the radiation protection objectives (i.e., reduce doses) rather than the first objective (i.e., avoid early fatalities and serious injuries).

The protective action guide limits were established at levels at which no early health effects would be expected (see Table 2.1), even for such sensitive populations as pregnant women and children.

Slide 9

At the lower end of the scale would be protective actions to control the total number of long-term cancers.

For radiation protection purposes it is assumed that, no matter how low the dose, some percentage of the population will eventually suffer from cancer because of the radiation exposure. The result is that consequence models project that most cancers

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Table 2.1. Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) Protective Action Guides (PAGs)

Organ	EPA PAGs for plume exposure[a] (rem)	FDA PAGs for food and agricultural products[b] (rem)
Whole body (bone)	1-5	0.5-5
Thyroid	5-25	1.5-15
Other body organs	1-5	0.5-5

[a]At a lower projected dose, protective actions should be considered; at a higher projected dose, protective actions would be warranted.

[b]At a lower projected dose, use of grazing land should be restricted; at a higher projected dose, contaminated milk should be impounded.

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would occur more than 50 miles from the plant. This is the result of a great number of people receiving a very low dose. Thus, as a practical matter, emergency-phase protective actions available to reduce these effects are very few. In the early time frame of a response, sheltering to long distances, where convenient, might be advised--much as for an air pollution alert.

2.3 PRINCIPAL SOURCE OF RADIATION DOSE CAUSING EARLY HEALTH EFFECTS

Slide 10

Only a very severe reactor accident involving core damage and containment failure could result in early death or injury. To examine consequences of such a severe accident, a representative accident will be discussed in detail. This accident is not based on a specific sequence but instead includes characteristics of many severe accidents.

Accident conditions that could result in a release to the atmosphere (called a PWR 4 in WASH-1400) were selected. This release includes about 60% of the noble gases and 5% to 10% of the iodine and cesium in the reactor core. This type of release could result from a core melt followed by a containment failure after some mechanism has removed a large fraction of the iodine, cesium, and other nongaseous fission from the containment atmosphere. This could include operation of containment sprays for a short period before the containment failure or could be the result of the containment holding for sufficient time (several hours) to allow the nongaseous fission products to settle out. This is not the largest accident that has been postulated. Accidents that involve core melt followed by a fast containment failure that does not allow for removal of the nongaseous fission products could result in much larger doses/consequences off site. These accidents are considered very unlikely but are also the type requiring prompt and effective protective actions to prevent health effects off site.

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Slide 11

For this example and other severe accidents, there would be numerous indicators in the control room of core damage/melt (e.g., core temperature readings). The emergency action levels that indicate core damage would be exceeded, which would lead to the classification of a General Emergency. At this point, the control room staff would know that the plant was beyond design because, if the system had operated as designed, core damage would have been prevented.

This example case assumes a catastrophic failure of the containment. The release from this type of failure represents the greatest off-site risk because a large part of the radioactive material in the containment atmosphere will be released in a short period (a puff release, 1 to 2 hr). A puff release could expose people near the plant to most of the plume shine and inhalation dose in about an hour or so after the release.

Catastrophic containment failures could result from hydrogen explosions, overpressurization, isolation valve failure, or some failure that allows containment bypass. There may be some indicators in the control room that containment conditions may result in a failure. None of these provide warning prior to the containment failure, and thus they cannot be used to predict when containment will fail.

Therefore, in the example case and for most severe accidents, the control room staff will know (1) that the core is damaged and (2) that a large amount of fission products in the containment atmosphere could be released if the containment fails. However, they will not be able to predict when the containment will fail (or even if it will fail). As discussed in Vols. 2 and 3, for most accidents studied, at least several hours would elapse between core damage and containment failure, thus allowing time to take protective actions before a release (if they are started upon detection of core damage).

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Slide 12

The major source of early injury- and death-producing dose for the most severe accidental releases would be the shine (gamma rays) from the passing cloud and ensuing ground contamination and doses from inhaled material. This can be seen from Fig. 2.1, which shows the relative contribution of various pathways to whole-body dose as a function of distance for this accident.

Figure 2.1 shows whole-body and thyroid dose vs distance and time for various pathways. These doses were calculated for an average day for this accident; thus, the answers (dose projections) could be somewhat higher or lower depending on the actual weather at the time (see NUREG-1062)*

The top right figure shows the contributions to the 24-hr whole body dose. The inhalation pathway would contribute the least to projected whole body dose; the cloud shine dose would be sublethal, but the additional 24-hr ground shine contribution would lead to projected doses in excess of the early injury threshold (100 rem) out to 7 miles or so and the early fatality threshold (200 rem) out to about 3 miles.

In this example, the early doses (cloud shine and inhalation) are not sufficient to cause early injuries, but they do exceed Environmental Protection Agency whole body protective action guides out to about 10 miles. Accidents have been postulated (no matter how unlikely) that could cause early injuries close to the plant resulting from plume shine and inhalation. This shows the importance of early protective actions. For an accident of this type involving a puff release of a few (1 to 2) hours' duration, the population close to the plant must take actions before or shortly after the start of the release to avoid a major portion of the dose from the plume shine and inhalation. Actions taken after the puff's passage are effective only in reducing dose from ground contamination.

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* See Appendix A of Vol. 1, "Bibliography for Volumes 1-5."

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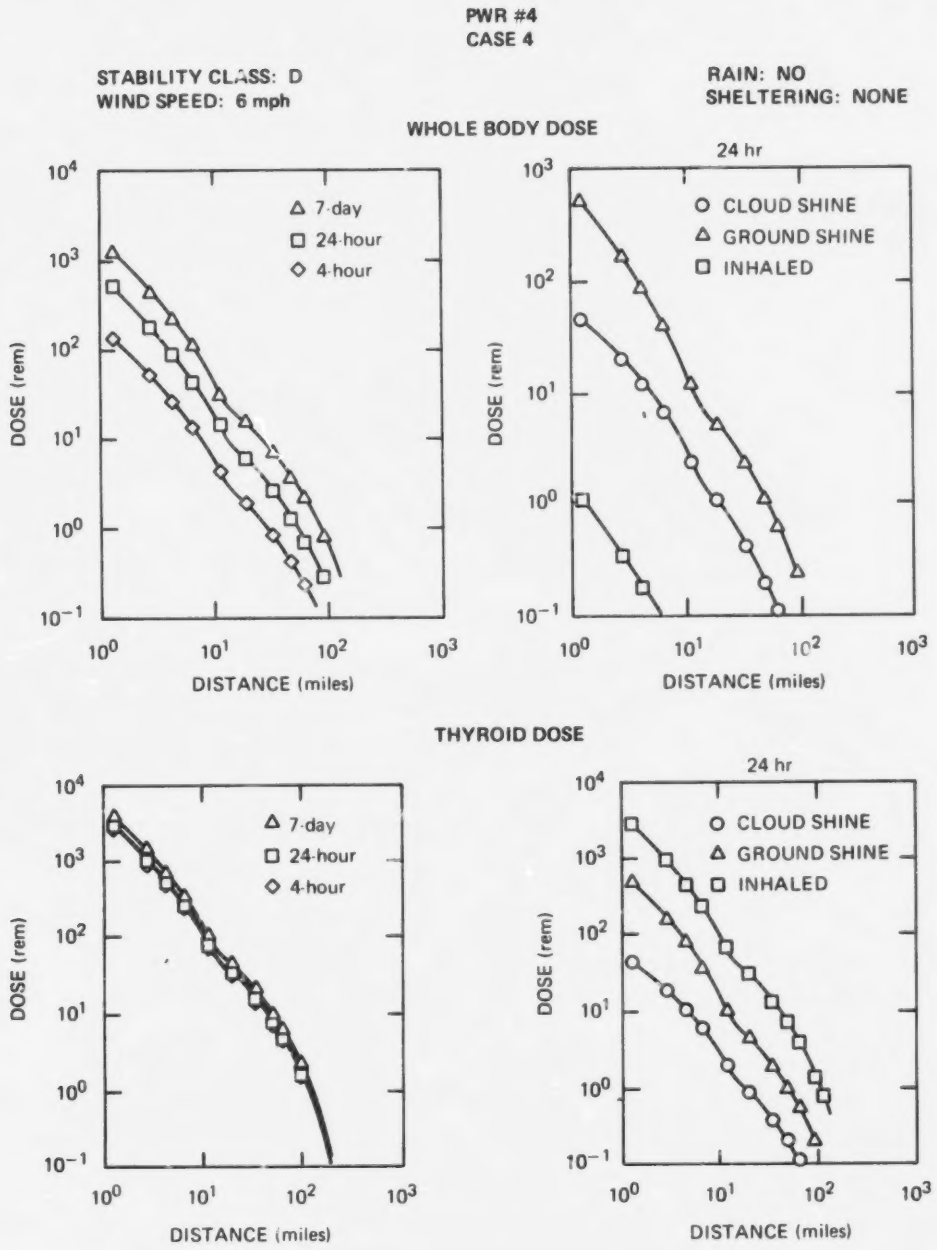

Fig. 2.1. Dose calculations for severe LWR accident scenarios (example from NUREG-1062).

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Most of the total dose increase between 4 hr and 7 days (shown in the top left figure) results from ground contamination deposited by the passing plume. This shows the importance of ground contamination. In this example, the direct dose from the plume is not sufficient to result in early deaths or injuries; but if people remain on contaminated ground, their dose will build until, at about 6 hr, the dose could result in injuries and, at 12 hr, cause death. Obviously, after a major release, areas of substantial ground contamination must be identified, and the population must be evacuated.

From the bottom figures, it can be seen that projected thyroid doses are controlled by inhalation doses, with the ground and cloud shine contribution increasing the dose only marginally within 24 hr. Thyroid ablation would occur at thyroid doses above about 1000 rem. This also would not be expected beyond about 3 miles for this accident.

Whole-body dose (not thyroid dose) would be the most important dose for most accidents in terms of early fatalities and injuries. It is also clear that the thyroid dose would arise predominantly from inhalation.

Although the ingestion pathways can be of concern at considerable distances from the release point (e.g., 50 miles or more), this concern is not discussed in this section. This section discusses only those actions that must be taken early in an accident to protect the population at greatest risk. Ingestion dose is not considered a major contribution to early health effects. For the ingestion pathway, the early protection actions are designed to minimize subsequent contamination of milk or other foods (e.g., remove cows from pasture and put them on stored foods). The specific actions and criteria for vegetables are addressed by the Food and Drug Administration protective action guides.

Another point to be made from the curves involves the plume exposure emergency planning zone (EPZ). Many think that the public risk stops at the boundary of the emergency planning zone. But, it is clear that this accident would result in doses in excess of the

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Environmental Protection Agency whole body (5 rem) and thyroid (25 rem) doses; at these levels, evacuation would be appropriate beyond the plume emergency planning zone.

Slides 13 and 14

As indicated, this is not the worst accident that has been postulated. The worst accident has the same general characteristics discussed here but with one exception. The release would be much larger and could result in early deaths or injuries near the plant. Table 2.2 shows the risk of receiving a lethal dose for one of the worst accidents postulated (PWR 1 from WASH 1400). While this accident results in releases somewhat larger (e.g., 20% to 50%) than some now consider possible, examination of its consequences will be useful. Table 2.2 shows the risk of early deaths for various distances and times after the release before the evacuation begins (overlap time). For example, a 5-hr overlap time means that people did not start to move (evacuate) until 5 hr after the start of the release, while a negative 1-hr overlap time means the evacuation started 1 hr before the release. At the bottom of the table are shown the risks for long periods of shelter or normal activity. This table clearly shows three things:

1. Evacuation must begin before or shortly after a release to reduce risk substantially.

2. Movement of even short distances (e.g., 3 miles) results in substantial reduction in risk.

3. Shelter close to the plant for long periods may not be an effective protective action.

This illustrates that protective actions must first concentrate on the area near the plant.

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Table 2.2. Average individual risk of early fatality vs distance from the reactor for a PWR 1A release

Release overlap period (time elapsed after release before movement begins) (hr)	Distance from the reactor (miles)			
	0 to 1	1 to 2	2 to 3	3 to 3.5
5.0	0.11	0.04	0.01	$6X10^{-3}$
3.0	0.09	0.03	$7X10^{-3}$	$3X10^{-3}$
1.0	0.09	0.03	0.01	$7X10^{-3}$
0.75	0.09	0.03	0.01	$7X10^{-3}$
0.5	0.12	0.04	0.01	$5X10^{-3}$
0.25	0.09	0.02	$4X10^{-3}$	$1X10^{-3}$
0	0.01	$1X10^{-3}$	[a]	[a]
-0.5	[a]	[a]	[a]	[a]
-1.0	[a]	[a]	[a]	[a]
Poor Sheltering for 12 hr				
	0.11	0.05	0.01	$9X10^{-3}$
Best Sheltering for 6 hr				
	0.07	0.02	$4X10^{-3}$	$2X10^{-3}$
No response for 24 hr				
	0.12	0.07	0.03	0.02

[a]Values are less than 10^{-5}.

Source: NUREG/CR-2925.

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Slides 15 and 16

In this case, these actions would be directed toward preventing early deaths in the area within 2 to 3 miles of the plant. This basic concept applies to all reactor accidents because of the natural drop in plume concentration, and therefore dose, at larger distances. Figure 2.2 shows the relative dose reduction for average weather conditions. Obviously, the greatest reductions occur within the first 2 to 3 miles. Therefore, independent of the size of the release, the greatest need for protective actions most likely will be within 2 to 3 miles of the plant. For large releases, these actions will be to prevent early deaths and, for lesser releases, to keep doses below Environmental Protection Agency protective action guides. These conclusions are confirmed by Table 2.2.

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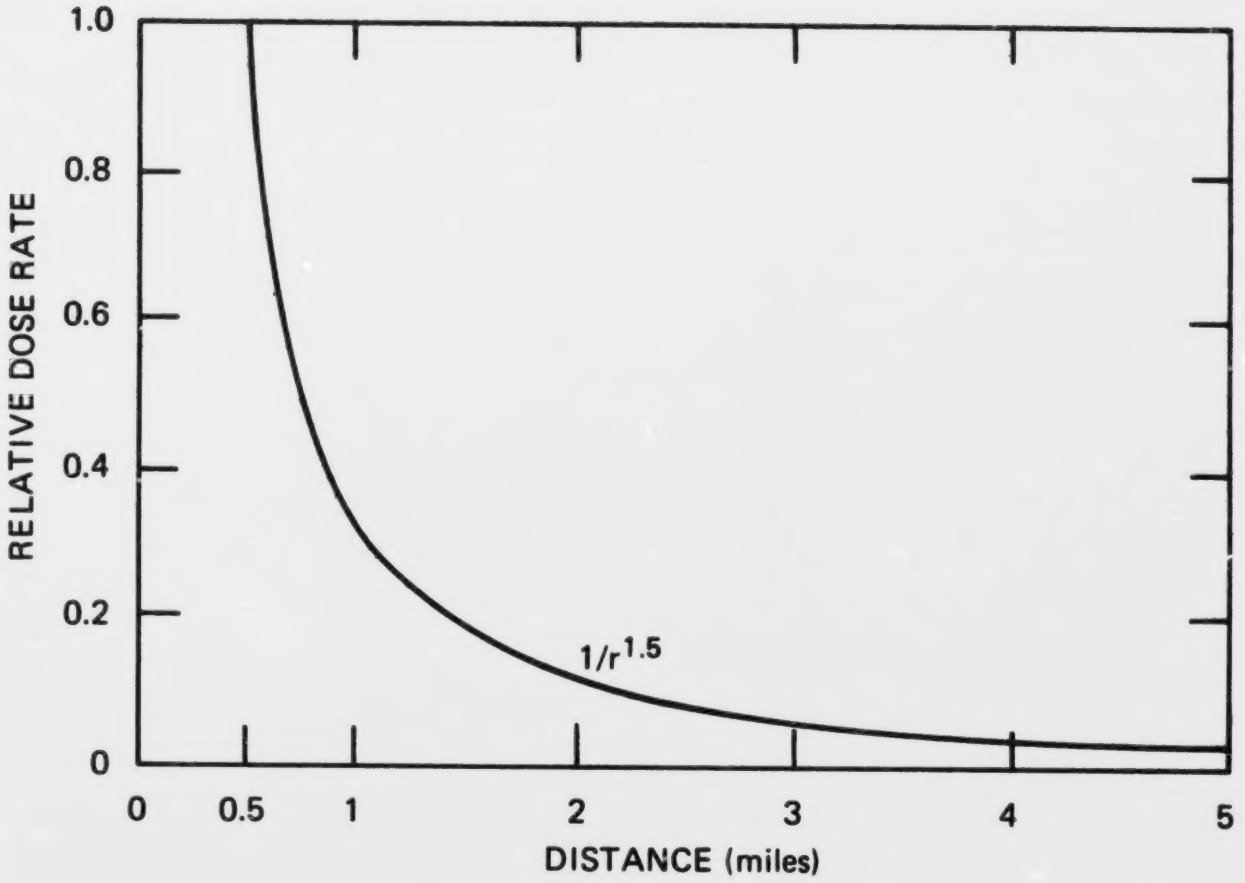

Fig. 2.2. General relationship of dose rate and distance for a ground-level atmospheric release.

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3. POTENTIAL PROTECTIVE ACTIONS

Slide 17

Once a decision has been made that a protective action is warranted, the type of protective action to be taken must be selected. Again, the initial, early protective actions to be recommended to the public under a given set of emergency conditions should be determined in advance (predetermined) if at all possible. However, adjustments to preplanned actions may be required at times if specific local conditions warrant. Four potential emergency actions will be discussed in Sects. 3.1 through 3.4: (1) evacuation, (2) sheltering, (3) improvised respiratory protection, and (4) use of potassium iodide (KI) as a thyroid-blocking agent for radioiodine.

3.1 EVACUATION

Slide 18

As discussed earlier, for the most severe accidents, evacuation near the plant (within 2 to 3 miles) may be the only option that can result in avoidance of early health effects; sheltering alone may not be an effective emergency response near the plant. Early evacuation of the area near the plant has several benefits in terms of public safety:

1. Shine dose from all or at least part of the external plume can be avoided (if the evacuation begins before or shortly after the release).

2. Shine dose from contaminated ground and other surfaces can be avoided.

3. Inhalation of contaminated air can be avoided.

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4. The highest-risk areas would have been cleared early, thereby alleviating the major decision-making tasks for emergency response teams.

In contrast, sheltering only reduces exposures (and only moderately in a small farmhouse); it does not avoid them. Consequently, emergency planners must continue to be concerned about people in shelters.

At certain times, evacuation may not be practical. For example, if an ice storm is in progress, major transportation arteries are blocked, or a major population center is involved, ordering an evacuation may result in entrapment of persons outside, where they may be more vulnerable than in their original locations. However, predetermined evacuation recommendations should be cancelled only if entrapment conditions are going to delay evacuation for many hours. The emergency response organization should always motivate people to evacuate areas near the plant if at all possible--for cause, of course (General Emergency). If early evacuation is simply not possible, emergency personnel should monitor for ground contamination following a release, if any, and motivate people to leave any areas found to contain large amounts of contamination (i.e., "hot spots"). Most likely, it will not be necessary for people to move very far from such heavily contaminated areas to reduce significantly their exposure from this pathway.

Slide 19

A concern exists that, once a release of material from a severe reactor accident starts, an evacuation should not be recommended because the evacuees may run into or be overtaken by the plume. For areas near the plant, this should be of minimal concern. Sheltering in most homes can reduce a person's dose by no more than about a factor of 2, while doubling the distance between the exposed person and the source of the exposure reduces the dose by a factor of 4. Therefore, it is still better for people to move out of areas near the plant (2 to 3 miles) if at all possible, even

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if the release of radioactivity has already started. The only exception to this, as noted previously, is under severe entrapment conditions (e.g., a snow or ice storm because a car is not as good a shelter as a house).

However, severe entrapment problems are expected to be rare at most reactor sites in the United States and especially rare in conjunction with a General Emergency. At most U.S. nuclear reactor sites, fewer than 300 people live within the first 2 to 3 miles around the plant. Within this distance there are few facilities such as hospitals that would require special attention in the event of an evacuation order. At a few reactor sites, however, all these conditions are not met. The emergency planner (and responder) must recognize that evacuation would be more difficult at these latter sites, and contingency plans must be prepared and decisions made accordingly in the planning process. It must always be remembered, though, that (1) for all sites, early evacuation of nearby areas would be most beneficial and (2) for the most severe accidents, early evacuation would be the only protective action available to achieve basic radiation protection objectives near the plant.

3.2 SHELTERING

Slide 20

Early sheltering appears to be an appropriate protective action measure

1. for areas where the risk of exceeding the doses required for early severe health effects is relatively low,

2. for lesser events (e.g., Site Area Emergencies) where a major release is not expected,

3. if severe entrapment problems are likely to occur if an evacuation is attempted,

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4. at long distances, where the threat of early fatality and injury is very remote (i.e., beyond the emergency planning zone), or

5. where a large population density makes entrapment outside very likely.

Numerous studies indicate that, beyond 2 to 3 miles of the plant under severe accident conditions, sheltering followed by post-release monitoring and relocation from "hot spots" would be as effective as evacuation in meeting the basic protective action objectives. This may not be true under certain meteorological conditions, such as if the radioactive plume passes through rainfall or if severe inversion conditions trap and confine the plume near the ground. Such conditions cannot be predicted with any useful degree of accuracy, and monitoring results (after a release) must be relied upon to determine when later evacuation at distances greater than 2 to 3 miles from the plant would be warranted.

Slide 21

Table 3.1 shows some factors that may be used to indicate the relative amount by which an exposure is reduced for various pathways as a result of sheltering in three different types of structures. These sheltering factors should be used for comparison purposes only, not for predictive purposes. They should be used to determine only the type of structure to recommend if a choice of structures is available. For cloud and ground shine, small farmhouses provide very little protection; but if a farmhouse has a basement, protection can be improved. Large concrete structures can provide a great deal of protection. Most likely, the uncertainties inherent in the early dose projection calculation will be far greater than the uncertainties in the listed sheltering factors.

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Table 3.1. Factors by which radionuclide exposure may be reduced by sheltering for different types of shelters and pathways of exposure

Type of shelter	Cloud shine	Ground shine	Inhalation exposure
Small, frame building			
Without basement	1	2	2[a]
With basement	3	5-10	3[a]
Multiple-story, concrete structure	5	10	5

[a]Puff release only.

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The inhalation protection provided will depend on the duration of the material in the area outside and on the "openness" or ventilation rate of the building. Small dwellings with closed windows and doors ventilate at a rate of about one air turnover per hour. For a 1-hr puff, a protection factor of about 3 (two-thirds reduction in dose commitment rate) can be achieved in a small dwelling. For longer releases (plumes), the protection factor would be lower (assuming that the wind does not shift). For perspective, all major (life-threatening) releases resulting from core melt accidents would be 0- to 2-hr puffs. Less-severe (in quantity) releases could last much longer. Thus, the immediate shelter option would be most beneficial for reducing inhalation dose. However, inhalation dose is only a part of the whole body dose.

In summary, enclosed structures can offer protection from the inhalation pathway. The amount of protection depends on the "tightness" of the structure and the duration of the contamination in the surrounding air.

3.3 IMPROVISED RESPIRATORY PROTECTION

Slide 22

This action reduces only the inhalation exposure, not the exposure to cloud shine or the exposure to contaminated ground and other surfaces. However, it does reduce the dose to all organs (e.g., lungs) via the inhalation pathway and not just the dose to a single organ, as is the case with KI tablets, which reduce only the radioiodine dose to the thyroid. This could be important under some conditions where lung dose rather than whole-body dose could be more important in terms of health effects.

Since, for most severe accidents, inhalation dose is not most important, improvised respiratory protection, such as placing a towel over the mouth and nose, is a secondary protective action (i.e., it may be recommended in conjunction with evacuation or shelter). However, implementation of improvised respiratory protection should never delay implementation of other protective

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actions such as sheltering or evacuation.

Slide 23

To provide further perspective on this topic, Table 3.2 shows the results of experiments conducted using different types of improvised respiratory protection. Military personnel used various household items as protection and measured their efficiency in removing particles. Some results were remarkable; for example, a bath towel had an efficiency of 74% to 85%.

More recent experiments show that an efficiency of 90% can be achieved by using a surgeon's or painter's mask.

The use of a loose-fitting towel over the nose and mouth should reduce the inhalation exposure from small particulates by a factor of about 2 to 5. Babies can be lightly wrapped in blankets, such as they are for protection from wind and cold. Use of a tight-fitting heavy towel is expected to reduce particulate inhalation by about a factor of 10. Note, however, that exposure received through inhalation of gases is <u>not</u> reduced by either of these techniques. Basically, improvised respiratory protection could be used as a secondary protective action to provide some relatively unknown, nontrivial level of additional protection.

3.4 USE OF POTASSIUM IODIDE (KI)

Slide 24

It must be understood that use of the thyroid-blocking agent KI is not an adequate substitute for prompt evacuation or sheltering by the general population near a plant in response to a severe accident (General Emergency). Ingestion of KI will serve only to help reduce the dose to the thyroid caused by intake of radioiodine. The primary risk to the population from a severe accident is whole body dose, not the radioiodine dose to the thyroid. The Food and Drug Administration has recommended that KI be administered for projected doses >25 rem thyroid.

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Table 3.2. Respiratory protection provided by common household and personal items against aerosols of 1- to 5-μm particle size

	Number of thicknesses	Geometric mean efficiency (%)
Handkerchief, man's cotton	16	94.2
Toilet paper	3	91.4
Handkerchief, man's cotton	8	88.9
Handkerchief, man's cotton	Crumpled	88.1
Bath towel, turkish	2	85.1
Bath towel, turkish	1	73.9
Bed sheet, muslin	1	72.0
Bath towel, turkish (wet)	1	70.2
Shirt, cotton (wet)	1	65.9
Shirt, cotton	2	65.5
Handkerchief, woman's cotton (wet)	4	63.0
Handkerchief, man's cotton (wet)	1	62.6
Dress material, cotton (wet)	1	56.3
Handkerchief, woman's cotton	4	55.5
Slip rayon	1	50.0
Dress material, cotton	1	47.6
Shirt, cotton	1	34.6
Handkerchief, man's cotton	1	27.5

[a]Resistance obtained when checked immediately after hand wringing. This resistance began to decrease after about 1 min when the material started to dry.

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To be effective, KI must be taken just before or shortly after exposure to radioiodine (within 1 to 2 hr). Thus, to be potentially effective, it must be readily available (Martin, 1985a). Taking the recommended dosage of KI (130 mg) just before or at the time of exposure could block more than 90% of radioactive iodine uptake by the thyroid (see Fig. 3.1). A 130-mg dose of KI will deliver about 100 mg of stable iodine. If taken approximately 3 to 4 hr after acute exposure, only about 20% blocking could occur in some persons. Note that a small percentage of people could react adversely to KI, but the risk of a severe reaction is very small.

Slide 25

The NRC and the Federal Emergency Management Agency (FEMA) recommend predistribution of KI to predesignated emergency workers, site personnel, and institutionalized individuals who might find it difficult to evacuate during an emergency. FEMA has stated the federal position that predistribution of KI to the general public should not be required for a state or local emergency plan to be acceptable (FDA, 1978).

3.5 OTHER PROTECTIVE ACTIONS

Other protective actions such as decontamination of evacuees, milk contamination control, and reservoir (water) protection should also be part of the emergency response. These actions are not discussed here because their implementation <u>early</u> in an event (0 to 4 hr) would not be crucial to their effectiveness.

3.6 DIRECTION OF PROTECTIVE ACTION COVERAGE

Slide 26

The final question is in what direction protective action should be taken. Past practice has been to plan to initiate protective action only in a "downwind" direction. This appears to be a reasonable planning strategy because it would greatly limit

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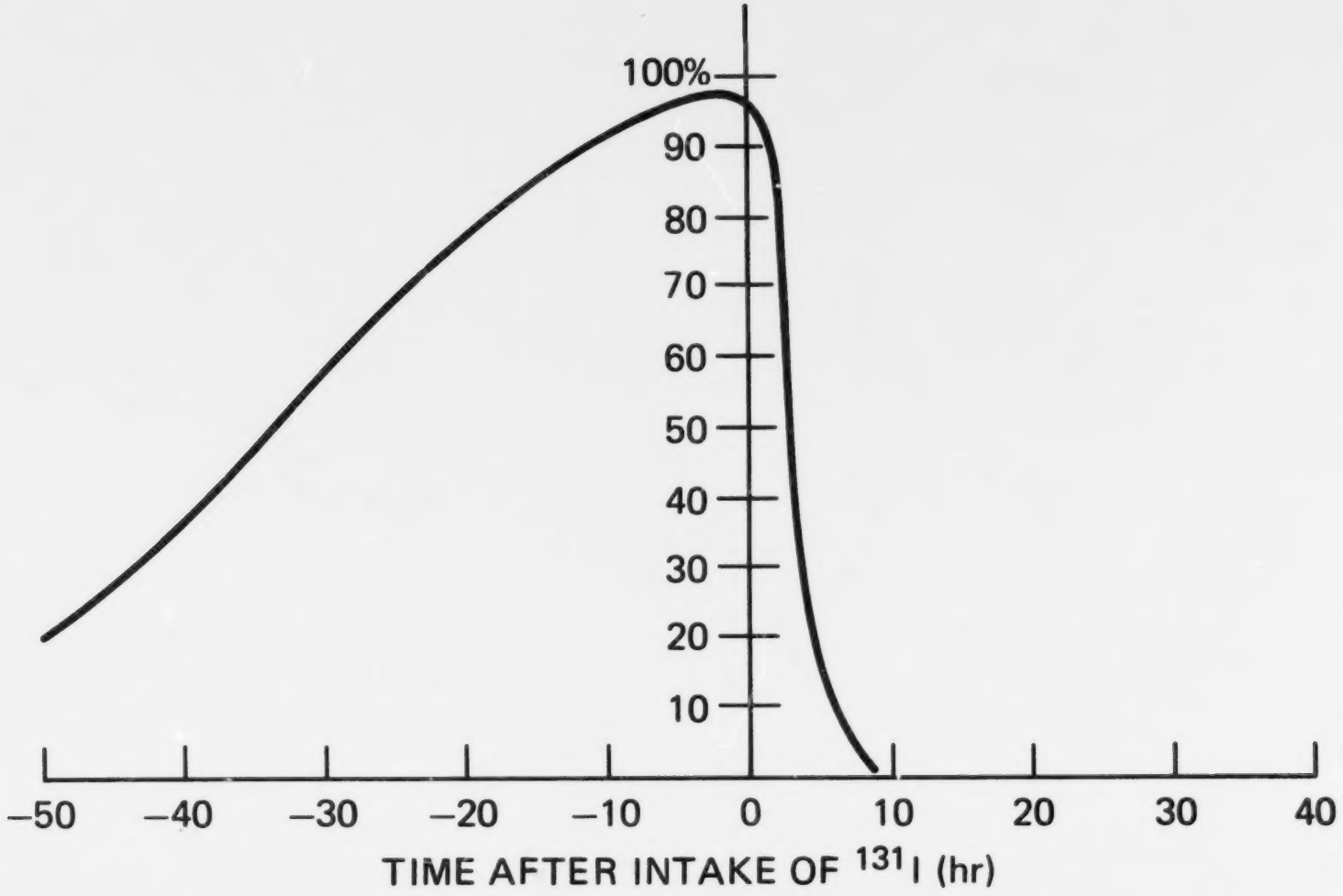

Fig. 3.1. Percent of thyroid blocking afforded by 100 mg* of stable iodine as a function of time of administration before or after a 1-μCi slug intake of ^{131}I.

—●— 130 mg of KI.

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the populations affected. The problem is that it would be difficult if not impossible in the early time frame to predict the magnitude and timing of a major release and where "downwind" would be at the time of a release. Moreover, "downwind" implies that an actual major release is underway. Emergency plans that call for awaiting a major release provide little, if any, risk reduction potential for the public. Therefore, the initial, early, precautionary evacuation near the plant should be effected in all directions.

3.7 BASES FOR PROTECTIVE ACTION

Slide 27

As discussed in Vol. 2, radiation doses in excess of Environmental Protection Agency protective action guides can occur as a result of the release of radionuclide material in the reactor coolant system or spent fuel storage pool. Protective action guides are well below doses that could result in early severe injury or fatality. Releases resulting in observable early health effects (injuries and deaths) or high individual risks (very high radiation doses) off site can occur only as a result of severe core damage coupled with early containment failure, either of which could occur first.

Slides 28 and 29

As discussed earlier, considerable research on severe accidents has been conducted to consider a great variety of conditions. This research has arrived at three basic conclusions concerning the effectiveness of early protective actions for preventing early health effects for very severe accidents and keeping doses below protective action guides for less-severe core melt accidents:

1. To be most effective, protective actions (shelter or evacuation) must be taken before or immediately upon a major release to the atmosphere.

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2. For core melt accidents, people should immediately evacuate areas near the plant (e.g., 2- to 3-mile radius) and remain in shelter elsewhere in the early time frame.

3. Following a major release, the dose from ground contamination may become very important in a few hours (e.g., 4 hr), requiring immediate radiological monitoring to locate hot spots (e.g., 1 R/hr or greater) caused by ground contamination.

4. Protective actions may be required beyond 10 miles.

The first conclusion is intuitively obvious. Moreover, a major, severe release would be very intense initially with the major portion of the radioactive material being released soon (e.g., 0.5 to 2 hr) after the start of the release; therefore, protective actions must be taken <u>early</u> where at all possible to be effective in avoiding or reducing this early dose.

The basis for the second conclusion is informed judgment, which takes into account three considerations. As discussed earlier, risk decreases rapidly up to a distance of about 2 to 3 miles and decreases more slowly thereafter. Thus, in the event of a core melt accident sequence, early evacuation of the first 2 to 3 miles would markedly reduce individual risks (i.e., the payoffs would be greatest within this distance). Second, the population within this distance is small (at many sites, a few hundred people), and there are normally few impediments to immediate evacuation of the area. Indeed, this area encompasses the low-population zone around most reactor sites. Third, the individual risk of early deaths or injuries for the most severe accident is, in most cases, confined to this area.

The basis for the third conclusion is also intuitively obvious. In the event of an actual major release, anyone found in shelter in an area of high ground-level contamination (e.g., >1 R/hr) would be asked to leave--whether or not an emergency plan calls for it. The predetermined level of 1 R/hr conforms to the

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Environmental Protection Agency protective action guide of 1 to 5 rems projected whole-body dose. As noted earlier, evacuation at lower dose rates could be recommended on an ad hoc basis; but for a very severe accident, the 1-R/hr level may be suitable as an initial predetermined "trip" level. The basis for the last conclusion is obvious from the discussion of severe accidents in Sect. 3.2, which showed doses in excess of Environmental Protection Agency protective action guides beyond 10 miles.

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4. SEVERE ACCIDENT PROTECTIVE ACTION

4.1 SEVERE ACCIDENT STRATEGY

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Any severe reactor accident (core damage accident) protective action strategy should attempt to address the basic conclusions, listed in Sect. 3.7, concerning effective protective actions to avoid early health effects.

The first conclusion requires that action be taken before or shortly after a release. As discussed in Vol. 2, this is one of the primary objectives for establishing emergency action levels that result in detection of core damage, declaration of a General Emergency, and recommendation of protective actions. As discussed earlier, core damage is required for a severe release, and control room indicators of core damage should be numerous. However, once core damage exists, the timing and size of a release cannot be projected. The best way to ensure that actions are started before a release is to initiate them as soon as core damage is detected. If the decision to take action awaits a dose projection (if possible) or field monitoring results, obviously the population close to the plant could be exposed to a large part of a puff release.

For most core damage incidents, protective actions may not be necessary because a major release is not expected (e.g., the Three Mile Island accident). However, core damage accidents are expected to occur only a few times at most, and the results of not taking immediate protective actions could be tragic.

The second and third conclusions in Sect. 3.7, calling for evacuation near the plant and monitoring after a major release, have been incorporated directly into NRC's guidance. The guidance addresses the second protective action objective (reducing dose above Environmental Protection Agency protective action guide levels) by directing adjustment of early actions based on assessment against the protective action guides. It is important to note that this is done after the initial actions are taken to

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protect against the possibility of early health effects near the plant.

4.2 BASIC GUIDANCE

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The specific NRC guidance from NUREG 0654 for General Emergency protective actions is summarized in Table 4.1 and shown in detail in Fig. 4.1. The diagram in Fig. 4.1 was sent to licensees in Information Notice 83-28. Several points concerning Fig. 4.1 should be discussed. Initial scoping of an emergency is to be based on plant observables* (emergency action levels) predetermined to identify the plant conditions referred to in the diagram (e.g., 20% cladding failure, fission products in containment, or containment status). Early in an accident sequence, enough time would not be available to calculate the relationship between some instrument readings and a plant condition. Core damage is defined (Fig. 4.1, Note 2) as release of 20% of the gap activity from the core (see Vol. 2). This level of core damage (release) was chosen because it is well beyond that expected for any accident if safety systems operate as planned; moreover, the in-plant consequences should be readily observable (e.g., high core temperature or highly elevated in-plant dose rates in water and/or air).

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The criteria also call for evacuation in what is called a keyhole, that is, in all directions close to the plant and in the downwind direction farther away (e.g., a 2-mile radius and 5 miles downwind). This ensures that people at greatest risk would evacuate early in the event of a General Emergency. Figure 4.2 shows a typical keyhole evacuation area. Note that the actual

* Protective action guides, being projected doses, are not observables; thus, they cannot be acceptable bases for protective action decisions in real time. Emergency action levels form the desired (required) bases.

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Table 4.1. Summary of NUREG-0654 protective action guidance

Emergency class/ plant condition	Predetermined protective action
Notification of an Unusual Event	None
Alert	None
Site Area Emergency	None
General Emergency	
First priority[a]	
General emergency declared	Those near the plant should take shelter (Get people inside to receive further instructions)
Catastrophic containment failure not imminent[b]	Evacuate areas near the site
Catastrophic containment failure imminent[b]	Evacuate areas near the plant that can be evacuated before "puff" arrival; others should take shelter
Second priority	
Dose projections vs EPA PAGs	Extend protective action area (as necessary) if this will not interfere with immediate actions near the plant
Following a release	
Locate highly contaminated areas	Promptly evacuate highly contaminated areas

[a]Whenever possible, these actions should be taken before a release, based on core and containment status (EALs).

[b]Catastrophic failure consists of the release of a major portion of the radioactive materials in the containment over a short time (e.g., 1 hr) (i.e., a "puff" release). Most experts believe that this type of containment failure is unlikely. Containment performance would be very difficult to predict during the early phases of a core melt accident.

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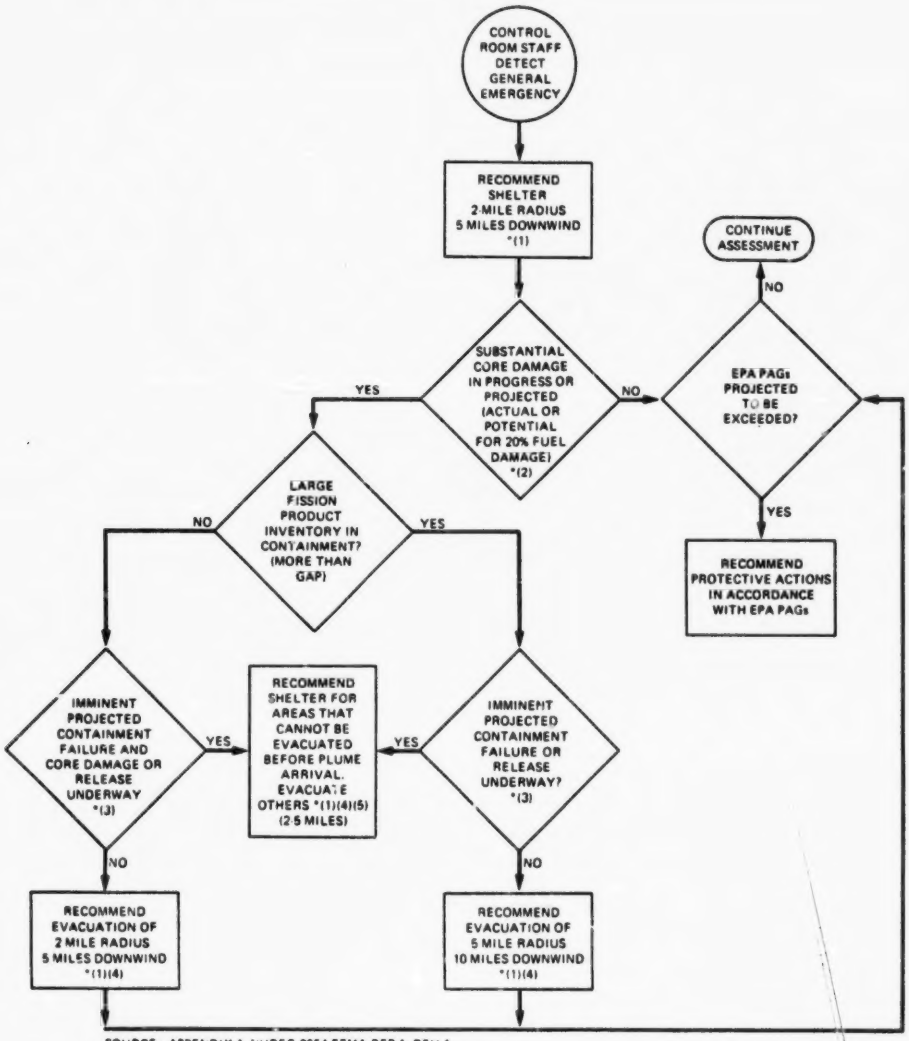
THE FOLLOWING ACTIONS WILL BE BASED ON PREDETERMINED OBSERVABLE INSTRUMENTATION AND PLANT STATUS INDICATORS (EALs) CONTAINED IN THE EMERGENCY PLAN AND THAT HAVE BEEN REVIEWED BY OFFSITE OFFICIALS. HOWEVER, RESPONSIBLE OFFSITE OFFICIALS MUST DECIDE ON THE FEASIBILITY OF IMPLEMENTING THE PROTECTIVE ACTIONS AT THE TIME OF THE ACCIDENT.


CONTROL ROOM STAFF DETECT GENERAL EMERGENCY
RECOMMEND SHELTER 2 MILE RADIUS 5 MILES DOWNWIND *(1)
CONTINUE ASSESSMENT
NO
SUBSTANTIAL CORE DAMAGE IN PROGRESS OR PROJECTED (ACTUAL OR POTENTIAL FOR 20% FUEL DAMAGE) *(2)
YES
NO
EPA PAGs PROJECTED TO BE EXCEEDED?
YES
RECOMMEND PROTECTIVE ACTIONS IN ACCORDANCE WITH EPA PAGs
LARGE FISSION PRODUCT INVENTORY IN CONTAINMENT? (MORE THAN GAP)
NO
YES
IMMINENT PROJECTED CONTAINMENT FAILURE AND CORE DAMAGE OR RELEASE UNDERWAY *(3)
YES
RECOMMEND SHELTER FOR AREAS THAT CANNOT BE EVACUATED BEFORE PLUME ARRIVAL. EVACUATE OTHERS *(1)(4)(5) (2-5 MILES)
YES
IMMINENT PROJECTED CONTAINMENT FAILURE OR RELEASE UNDERWAY? *(3)
NO
NO
RECOMMEND EVACUATION OF 2 MILE RADIUS 5 MILES DOWNWIND *(1)(4)
RECOMMEND EVACUATION OF 5 MILE RADIUS 10 MILES DOWNWIND *(1)(4)

SOURCE: APPENDIX 1, NUREG 0654 FEMA REP 1, REV 1.

*(1) SITUATIONS REQUIRING URGENT ACTION BY OFFSITE OFFICIALS (BASED ON CONTROL ROOM INDICATORS. NO DOSE PROJECTIONS REQUIRED) – 15 MINUTE DECISIONMAKING, ACTIVATION OF ALERTING SYSTEM AND EBS MESSAGE

*(2) ACTUAL OR PROJECTED RELEASE OF 20% GAP FROM CORE OR LOSS OF PHYSICAL CONTROL OF THE PLANT TO INTRUDERS

*(3) "PUFF" RELEASE (RATE MUCH GREATER THAN DESIGNED LEAK RATE)

*(4) FOR ALL EVACUATIONS, SHELTER THE REMAINDER OF THE PLUME EPZ AND PROMPTLY RELOCATE THE POPULATION AFFECTED BY ANY GROUND CONTAMINATION FOLLOWING PLUME PASSAGE

*(5) CONCENTRATE ON EVACUATION OF AREAS NEAR THE PLANT (e.g., MAY BE TIME TO EVACUATE 2 MILE RADIUS AND NOT THE 5 MILE RADIUS)

Fig. 4.1. Flow chart of the Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants in NUREG-0654 (Information Notice 83-28).

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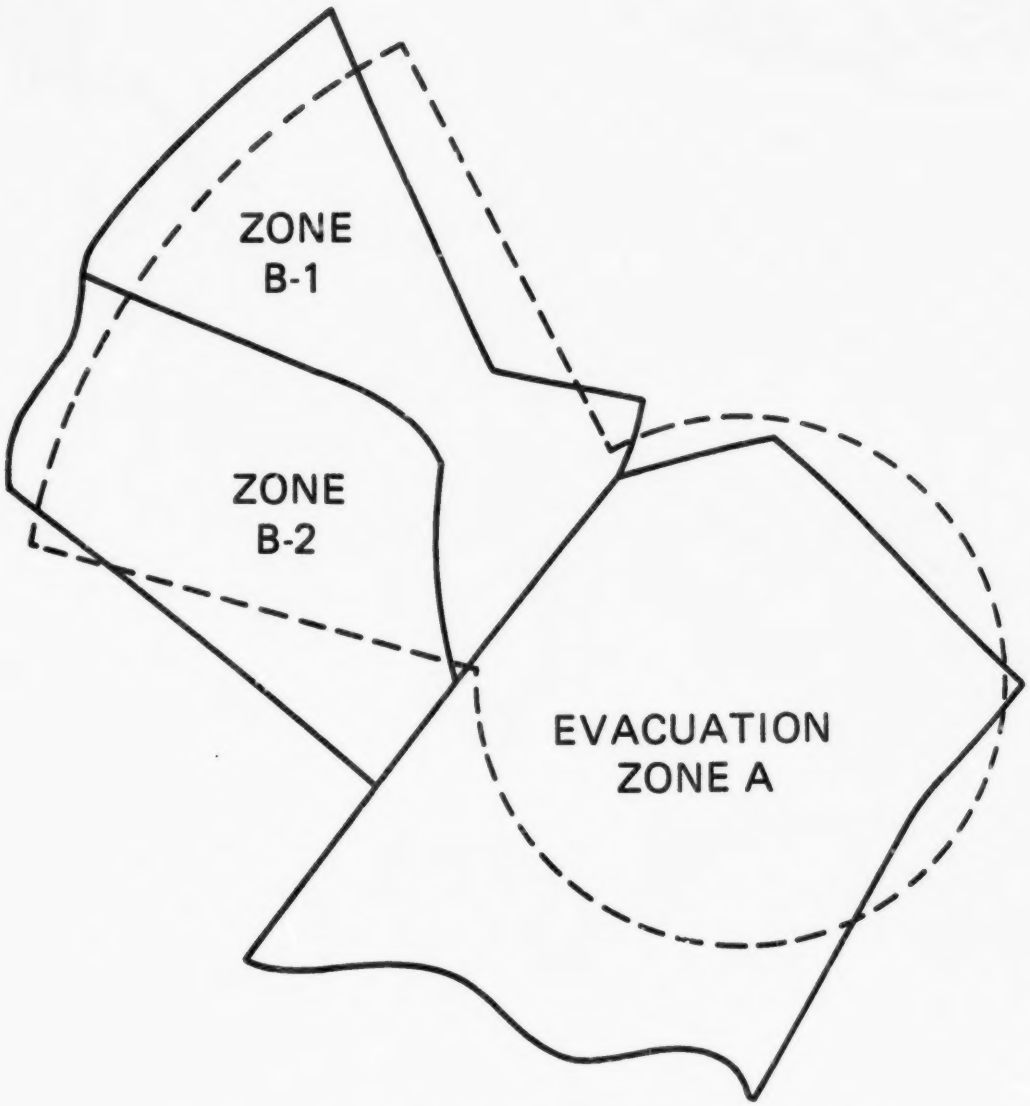

Fig. 4.2. Typical keyhole.

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evacuation zone boundaries are preplanned based on local conditions (e.g., roads, population density, and total population).

Slide 34

This guidance indicates that people close to the plant should not evacuate if imminent catastrophic containment failure that could release large fractions of the radioactive material in a puff (<1 hr) is likely. The goal is to shelter people inside their homes as the puff release moves by. [This is effective only for puff releases (short duration).] For a long-duration release, most of the release and accompanying dose can be avoided by early evacuation. Therefore, effective application requires that the duration of the release be known (predictable), which probably would not be the case early in a severe accident sequence.

In most cases, puff releases would be the result of containment failures that were (1) unpredictable (e.g., bypass accidents or explosions) or (2) the result of overpressurization. Currently, containments are not estimated to fail until pressures two or three times the design pressure are reached. These pressures should not be reached for many hours following the start of a contained core melt accident. Overpressurization failures would be far from imminent (following detection of core damage), allowing considerable time for precautionary evacuation of areas near the plant. In addition, the exact timing of a failure due to overpressurization would not be predictable.

Consequently, this part of the criteria appears to be applicable only for those situations where the timing of a puff release is certain. An example would be the controlled venting of the containment by the licensee. Therefore, for protective action implementation in general, it should be assumed that the containment will <u>not</u> fail catastrophically and result in a puff release. Prudence dictates that, if core melt is indicated, people near the plant should evacuate, if at all possible, as a precautionary measure.

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Following implementation of initial, early protective action recommendations near the plant, dose projections and field monitoring should be performed. Dose projections will be used to determine if protective actions should be expanded according to the Environmental Protection Agency protective action guides shown in Table 2.1. As is also discussed in Vol. 2, great uncertainties are associated with dose projection. Therefore, dose projections should be very suspect. As soon as possible after a release, field monitoring data should be the preferred basis for expanding initial protective actions.

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Table 4.2 summarizes Environmental Protection Agency recommended protective action criteria, planned actions, and contingency options. Several items in this table are especially important. First, for projected doses above 5 rem whole body or 25 rem thyroid, mandatory evacuation is recommended--but sheltering would be a fallback position for situations where evacuation is not immediately possible. Even for a projected dose of 1 rem whole body or 5 rem thyroid, evacuation would be preferred. Second, below a projected dose of 1 rem whole body or 5 rem thyroid, no planned (i.e., predetermined) protective action would be warranted. However, ad hoc decisions are provided for on a case-by-case basis (see footnotes to Table 4.2).

4.3 BENEFITS OF SEVERE ACCIDENT PROTECTIVE ACTION GUIDANCE

Slide 37

Declaration of a General Emergency (severe core damage) should result in the following minimally acceptable sequence of initial protective actions:

- immediate precautionary evacuation, where possible, of areas near the site;

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Table 4.2. EPA's recommended protective actions to reduce whole-body and thyroid dose from exposure to a gaseous plume

Projected Dose (rem)		Recommended actions[a]	Comments
Whole body	Thyroid		
		Population	
<1	<5	No planned protective actions[b] State may issue an advisory to seek shelter and await further instructions Monitor environmental radiation levels	Previously recommended protective actions may be considered or terminated
1 to <5	5 to <25	Seek shelter as a minimum Consider evacuation. Evacuate unless constraints make it impractical Monitor environmental radiation levels Control access	If constraints exist, special consideration should be given for evacuation of children and pregnant women
5 and above	25 and above	Conduct mandatory evacuation Monitor environmental radiation levels and adjust area for mandatory evacuation based on these levels Control access	Seeking shelter would be an alternative if evacuation were not immediately possible
		Emergency team workers	
25	125	Control exposure of emergency team members to these except for lifesaving missions. (Appropriate controls for emergency workers include time limitations, respirators, and stable iodine.)	Although respirators and stable iodine should be used where effective to control dose to emergency team workers, thyroid dose may not be a limiting factor for lifesaving missions
75		Control exposure of emergency team members performing lifesaving missions to this level. (Control of time of exposure will be most effective.)	

[a]These actions are recommended for planning purposes. Protective action decisions at the time of the incident must take existing conditions into consideration.

[b]At the time of the incident, officials may implement low-impact protective actions in keeping with the principle of maintaining radiation exposures as low as reasonably achievable.

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- immediate sheltering elsewhere; and

- if a major release occurs, relocation from sheltered areas in which high dose rates are evident, as determined by radiological monitoring teams. (Dose rates in excess of 1 R/hr would be considered high.)

To examine the effectiveness of these actions for a very severe accident, a calculation was made assuming the greatest accidental release (i.e., source term) currently considered possible. It was further assumed that people within 1, 2, or 3 miles of a site would leave at a speed of 10 miles/hr, starting 0.5 hr after the beginning of the release (i.e., a somewhat pessimistic time delay after initiation of the release). People outside these early evacuation radii were presumed to seek shelter in basements of homes. People in shelters within 10 miles were relocated after 4 hr of exposure to ground contamination (in addition to the puff); people farther than 10 miles were relocated after 8 hr of exposure to ground contamination (also in addition to the puff).

These relocation times were used as estimates of the time that might be required for monitoring teams to locate hot spots and warn and motivate the people and for people to leave. The CRAC2 computer code was used to perform the calculations for a typical 800-MW(e) reactor at a site in the northeastern United States. Actual population distributions were used. These are idealized assumptions, but the results are indicative of the potential benefits of the predetermined protective action scheme.

As shown by the $1/r^{1.5}$ dose-vs-distance curve in Fig. 2.2, risk decreases rapidly within the first few miles of a potential atmospheric release point. Results of the previously described calculations bear out this observation, as displayed in Fig. 4.3. This figure displays the conditional risk of an early fatality for early (0.5 hr after start of the release) evacuation radii of 1, 2, and 3 miles and 24 hr of normal activity (no protective actions). The specific dose/risk projections from this type of calculations are not very meaningful; but when used to compare various options,

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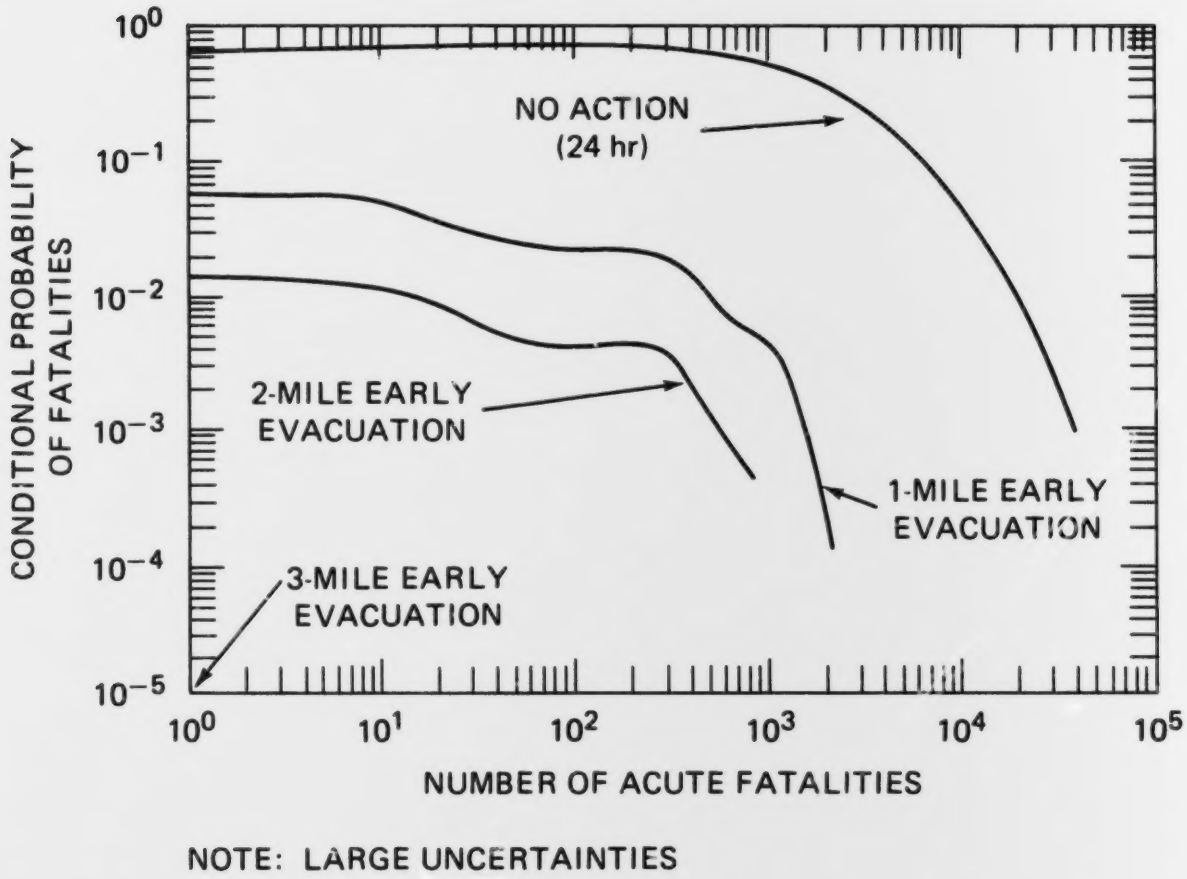

Fig. 4.3. Conditional probabilities of various numbers of acute fatalities, assuming the largest reactor accident, early evacuation of small areas, and a slow relocation from highly contaminated areas.

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they are useful. In this case, they show a reduction of a factor of 10,000 in the possibility of early fatalities when there is early evacuation of the area near the plant. The risk of an early fatality was greatly reduced by using the 3-mile evacuation radius assumption. Although zero fatalities were calculated for the 3-mile early evacuation case, this in no way represents a prediction for the noted assumptions. Nevertheless, the potential benefits of the recommended 2- to 3-mile early evacuation/shelter/relocation scheme are evident from this example.

This also indicates the importance of monitoring to locate ground contamination and for the sheltered population to relocate from hot spots quickly. In this case the people were (in essence) assumed to evacuate if the ground contamination was 1 R/hr (about 100,000 times the normal background dose rate).

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The basic conclusions are that, even for the worst possible accident, virtually all early fatalities can be prevented if the area near the plant (2 to 3 miles) is evacuated before or shortly after a release and if prompt monitoring is conducted to locate ground contamination that would result in expeditious relocation of people sheltered elsewhere.

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5. IMPLEMENTATION

5.1 ENTRAPMENT SCENARIOS

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Objections to the predetermined protective action scheme can be raised. Indeed, it is not perfect. There is no guarantee that all persons would receive low exposures, given their respective particular situations at all times. Many scenarios can be readily conceptualized for which the predetermined action scheme would not be the best (or even an available) response. However, coincidences of core melt and major impediments to immediate evacuation of small areas by most people should be extremely rare. Expedient shelter of some sort is always available.

Entrapment scenarios are simple to postulate. Patent entrapment scenarios can be postulated (e.g., conditions resulting from a major earthquake). For the most part, such scenarios are entrapment by definition; by postulate, there is no way out. Under these conditions, local officials must use common sense in providing the best shelter and/or evacuation possible.

5.2 PUBLIC RESPONSE

Slide 40

Objections have been raised to evacuation because of fears of panic or injuries during the evacuation. Evacuations of up to a few thousand people from areas up to about several square miles are not uncommon. Examples of evacuations of record are presented in Table 5.1. Evacuations of significant size occur about every week to ten days in the United States. (Keep a mental note every time you hear of an evacuation.)

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Table 5.1. Examples of large-scale evacuations

Date	Number of people evacuated	Place	Incident
6/30/78	3,000	Destrehan, La.	Rail car gas leak (styrene gas)
6/21/78	600,000	Salonika, Greece	Earthquake
5/15/78	1,000	Nacogdoches, Tex.	Chemical explosion; train wreck
4/25/78	1,500	Bowling Green, Ky.	Tank car containing poisonous gas ruptured
4/8/78	1,500	Brownson, Neb.	30-car derailment; tank car exploded (phosphorous)
4/6/78	2,000	Pineville, Ky.	Liquid propane tank car leak
4/1/78	2,500	Kingsburg, Ind.	Chemical plant fire; toxic fumes
3/15/78	2,000	Steubenville, Ohio	Chemical plant explosion; toxic chlorine fumes
3/8/78	1,200	Vicksburg, Miss.	Insecticide tank at chemical plant exploded
3/2/78	200	Galax, Va.	1,600-gal liquified propane spill
2/27/78	250	Youngstown, Fla.	Ruptured railway car; chlorine gas; wind shift noted
2/27/78	2,000	Waverly, Tenn.	Derailed tank car explosion; volatile propane
1/28/78	500	Damascus, Ark.	Leak from fuel tank (NO_4)
1/17/78	52	Pond Eddy, Pa.	11,000-gal acetaldehyde spill
12/29/77	800	Goldonna, La.	Chemical freight train crash
11/29/77	1,000	Norfolk, Neb.	Tank car carrying propane gas ruptured
11/28/77	771	Battle Creek, Neb.	Propane gas leak from tank car
11/8/77	1,000	Marion, Iowa	Tank car carrying propane gas ruptured
10/15/77	600	St. Marys, Kan.	Toxic fumes; unknown origin
10/13/77	800	Chattanooga, Tenn.	Gas fumes; elementary school
10/8/77	2,000	Midland, Mich.	Poisonous chlorine gas leak from chemical plant
10/4/77	160	Kansas City, Mo.	Elementary school; carbon monoxide leak
9/19/77	2,600	Berryville, Ark.	Fire at a fertilizer warehouse; ammonia and nitric acid
9/5/77	2,000	Watseka, Ill.	Railroad car derailed; ethylene oxide
7/13/77	5,200	Rockwood, Tenn.	Chemical truck wreck
5/17/77	2,000	International Falls, Minn.	Rail car leaked chlorine gas

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Table 5.1. (continued)

Date	Number of people evacuated	Place	Incident
12/11/76	10,000	Baton Rouge, La.	Chlorine gas leak at chemical plant
5/29/76	500	Centerville, Ill.	Toxic fumes release; two tank cars; chlorosulfonic acid and sulfuric acid
5/16/76	1,000	Glen Ellyn, Ill.	Tank car leaking toxic ammonia fumes
4/13/76	3,800a	Dwight, Ill.	Truck leaking liquid bromine

[a]Included evacuation of 209 severely retarded and handicapped children, only nine of whom could walk, and another 92 elderly patients from a different center. Total time consumed by the evacuation was 2 hr, and little confusion was noted. Public officials complained about the lack of resources.

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5.3 EVACUATION RISKS

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For perspective, the historical fatality risk of about 1/500,000 per person during evacuations may be compared to the conditional risk of an early fatality given a core-melt accident sequence. This cannot be done exactly. According to results of a limited number (i.e., about 15) of probabilistic risk analyses, roughly 1% to 10% of core melt accidents might result in a massive lethal release of radioactivity.

The evacuation risk of about 1/500,000 per person can be roughly compared to the 1/10 to 1/100 risk of a fatality given a core melt accident. Although this says nothing definitive about the risk for any particular core melt accident, it does indicate strongly that, on the average, it would be far less risky for an individual to leave the vicinity of a core melt accident than to stay--that is, evacuation would be the less risky alternative in the event of a core melt. Remember that, on a predetermined basis, an evacuation should not be recommended unless a core melt accident sequence is actually under way.

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It must also be remembered that few people live close to most nuclear power reactors. Figure 5.1, adapted from Demographic Statistics Pertaining to Nuclear Power Reactor Sites (NUREG-0348),* illustrates the number of people within 1 and 5 miles of 111 nuclear power plant sites (actual or proposed in 1979). Evidently, evacuations of everyone within a circular area of radius somewhere between 1 and 5 miles of these sites would be below the 10,000-person figure. At most sites, in fact, fewer than 300 people live within 2 miles of the site.

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* See Appendix A of Vol. 1, "Bibliography for Volumes 1-3."

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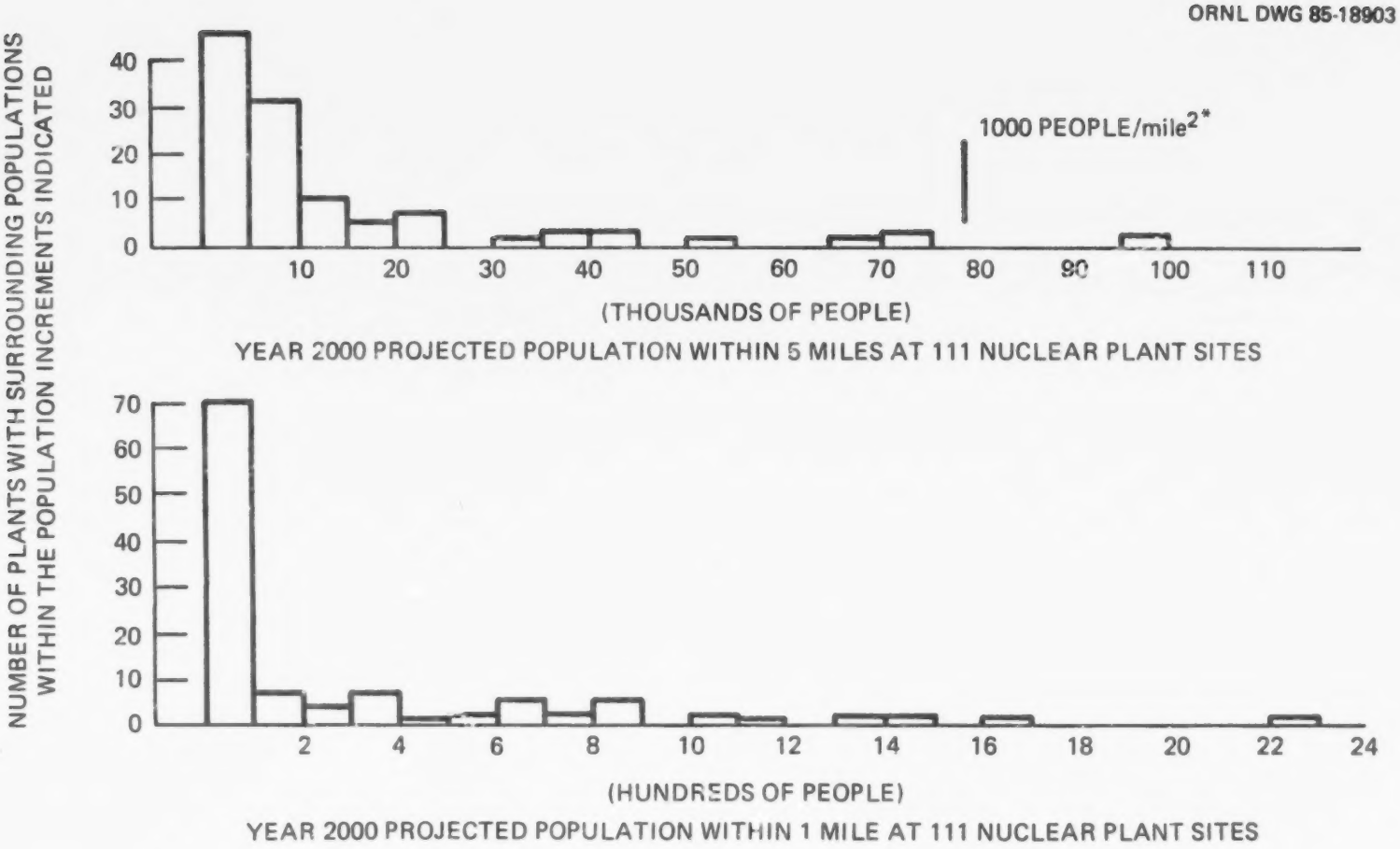

*1000 PEOPLE/mile^2 (DURING LIFETIME GUIDELINE) VALUE USED; ALL SITE POPULATION DATA NORMALIZED TO YEAR 2000 BY ESTIMATING PROJECTED POPULATION INCREASES.

Fig. 5.1. Number of people within 1 and 5 miles of 111 nuclear power plants, actual or proposed in 1979.

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5.4 PUBLIC BEHAVIOR DURING EMERGENCIES

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No nuclear accidents with severe off-site consequences have occurred in the United States. Other types of events have occurred that may indicate how people would respond to a nuclear accident. Objections to citing public behavior during nonnuclear emergencies for purposes of radiological emergency planning can and have been expressed, and the matter has been studied. More to the point, nuclear-related emergencies have occurred for which public behavior can be compared to that for nonnuclear emergencies.

The Environmental Protection Agency report Evacuation Risks--An Analysis found no reason to expect that people will react differently to a nuclear accident than they would to a flood, fire, or similar emergency.

Opinion, of course, is subject to scrutiny in the light of fact. Although the data base is limited, several nuclear-related incidents involving public response have occurred and can be compared to the nonnuclear experience. Some of these incidents (excluding weapons-related incidents) are presented in Table 5.2.

The accident that appears to be of the greatest relevance is Three Mile Island (TMI). The accident at TMI's Unit 2 occurred at 7:00 a.m. on March 28, 1979. By 8:00 a.m., the national television networks were broadcasting the news. A small percentage of the local population left the area during the first two days. On the third day (Friday), the governor of Pennsylvania recommended the evacuation of children and pregnant women. By the end of the weekend, about half of the population within 20 miles had left the area. Throughout this time, the people were subjected to intense stress and (to them) conflicting opinions and advice. Despite these conditions, the evacuations that occurred were orderly.

Some observers have stated that the evacuations represented panic. Conversely, it could be argued that the public's behavior was perfectly understandable considering the intense pressures to which they were subjected (e.g., various authorities expressed diametrically opposed positions, and some authorities even reversed

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Table 5.2. Public response to nuclear-related incidents

Date	Location	Incident	Public reaction
1957	Windscale, England	Accident at a graphite reactor caused the release of 20,000 Ci of radioiodine	Typical, no panic
1977	Ft. St. Vrain, Colo.	Erroneous reports of a release of 20 Ci/sec from a nuclear power reactor	Normal, no panic despite blizzard conditions
19__	Rocky Flats, Colo.	Major fire at plutonium plant	Normal, no panic or widespread flight
1980	Crystal River Plant, Fla.	20,000 gal of primary water was spilled into the containment	Normal, no panic or widespread flight
1979	Three Mile Island, Pa.	Nuclear power plant accident	Half of population within 20 miles evacuated within 5 days
1982	Rochester, N.Y.	Primary coolant released to the atmosphere from R. E. Ginna nuclear power plant	Normal, no panic or widespread flight
1981	Indian Point, N.Y.	Power transformer exploded when lightning struck a nuclear power station	Small-scale evacuation

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their own positions during the course of the accident). In fact, if the current protective action guidance had been in place at the time of the accident, evacuation of the area near the plant would have been recommended.

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Although fear and trauma are common in disaster situations, widespread panic (irrational behavior caused by stress) is uncommon to nonexistent. In fact, disaster victims often react with initiative, sometimes insisting on acting on their own against the expressed advice of public authorities. (Authorities might call this panic.) Furthermore, contrary to general assumptions, local organizations have generally proven themselves able to cope with emergencies rather than to be overwhelmed by them. Most disasters have not led to widespread antisocial behavior such as looting, nor do disasters destroy the morale of the communities involved. In many cases, the result of a disaster, over time, is an increase in the collective morale of the community.

During an evacuation, it can be expected that a small part of the population will not follow recommendations (e.g., evacuation) and that another group will evacuate on their own even if no shelter is recommended. However, most people will react calmly and normally to authoritative directions during an emergency. In media accounts of an evacuation, typically reporters will note with surprise that, instead of panicking, people helped each other. Although measures were taken to prevent looting, most often no looting was observed.

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In essence, the keys to a successful protective action strategy are early warning, clear instructions, and strong motivation provided to the audience by an authority figure such as a local newscaster, police chief, mayor, or governor.

Some fear and trauma should be expected in response to an evacuation order, but fears by authorities of widespread panic

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should not be an impediment to ordering an evacuation if grave cause exists.

5.5 ROLE OF THE NUCLEAR REGULATORY COMMISSION

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In cooperation with local officials, most licensees have developed site-specific criteria for recommending protective actions to the public according to the previously discussed concepts. Normally the NRC would not be part of the <u>early</u> predetermined protective action decision process. Licensees are required to report these events to off-site officials within 15 min and then immediately to the NRC (within 1 hr). It is expected to take an additional hour after notification for the NRC response organizations to be activated and be prepared to comment on protective action recommendations. Calling the NRC to confirm a preplanned protective action would only delay protective action implementation. Thus, the NRC staff may have little influence over early <u>response</u> actions, except by virtue of emergency <u>planning</u> appraisals.

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6. MAJOR POINTS

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- Protective actions have not been predetermined for less than core melt accidents.

- For core melt accidents, protective actions must be planned to be taken based on plant emergency action levels, preferably before a release. Projected dose is secondary to EALs as a basis for protective actions.

- Under most conditions, if core melt is indicated, people near the plant (2 to 3 miles) should be notified and motivated to leave immediately where at all possible.

- For core melt accidents, protective actions near the plant should be taken in all directions.

- For severe accidental releases to the atmosphere, the major threat is from the passing cloud, but ground contamination may dominate the dose in a few hours, especially where such releases intercept rainfall.

- At exceedingly low probability levels, protective action may be required even beyond 10 miles.

- Although core damage will be easy to detect, the future course of such an accident and containment response will be difficult to predict during a severe accident.

- The predetermined evacuation/shelter/relocation protective action scheme for a General Emergency can be demonstrated to provide significant risk reduction potential.

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- In the event of a core melt accident, off-site officials should implement early, initial protective actions without calling the NRC.

- Evacuations are not uncommon.

- Evacuations by up to a few thousand people have historically been a low-risk activity.

- Most people will react calmly and normally during an emergency evacuation.

- An evacuation order should not be delayed for fear of panic.

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Appendix A

SLIDES RELATING TO VOLUME 4 OF THE SEVERE REACTOR ACCIDENT INCIDENT RESPONSE TRAINING MANUAL

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APPENDIX A

SLIDES RELATING TO SEVERE REACTOR ACCIDENT INCIDENT RESPONSE TRAINING MANUAL:

PUBLIC PROTECTIVE ACTIONS – PREDETERMINED CRITERIA AND INITIAL ACTIONS

VOL. 4
NUREG/CR-3955
ORNL/TM-9271/V4

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Slide 1

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OBJECTIVES

- Describe
  - Basic radiation protection objectives for emergency response
  - Initial protective actions warranted for severe core damage accidents
  - Role and efficacy of other protective actions
  - Relationship of PAGs and EALs
  - Contributions to dose by various pathways of exposure
  - NRC severe accident guidance and its applications
  - Why evacuation recommendations should not be delayed for fear of panic or risk due to evacuation
  - NRC's role in the early implementation of predetermined protective actions

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NATURE OF THE THREAT

- Major release in the form of a plume or cloud
  - Radioactive gases
  - Radioactive particulates
  - Radioactive aerosols
- Plume may be
  - Prolonged
  - Very short (puff)
- Plume deposits radioactive particles on the ground and people (ground contamination)
- Risk from the plume
  - Same as from other hazardous clouds
  - Avoid immersion and inhalation
  - Not hazardous in other ways

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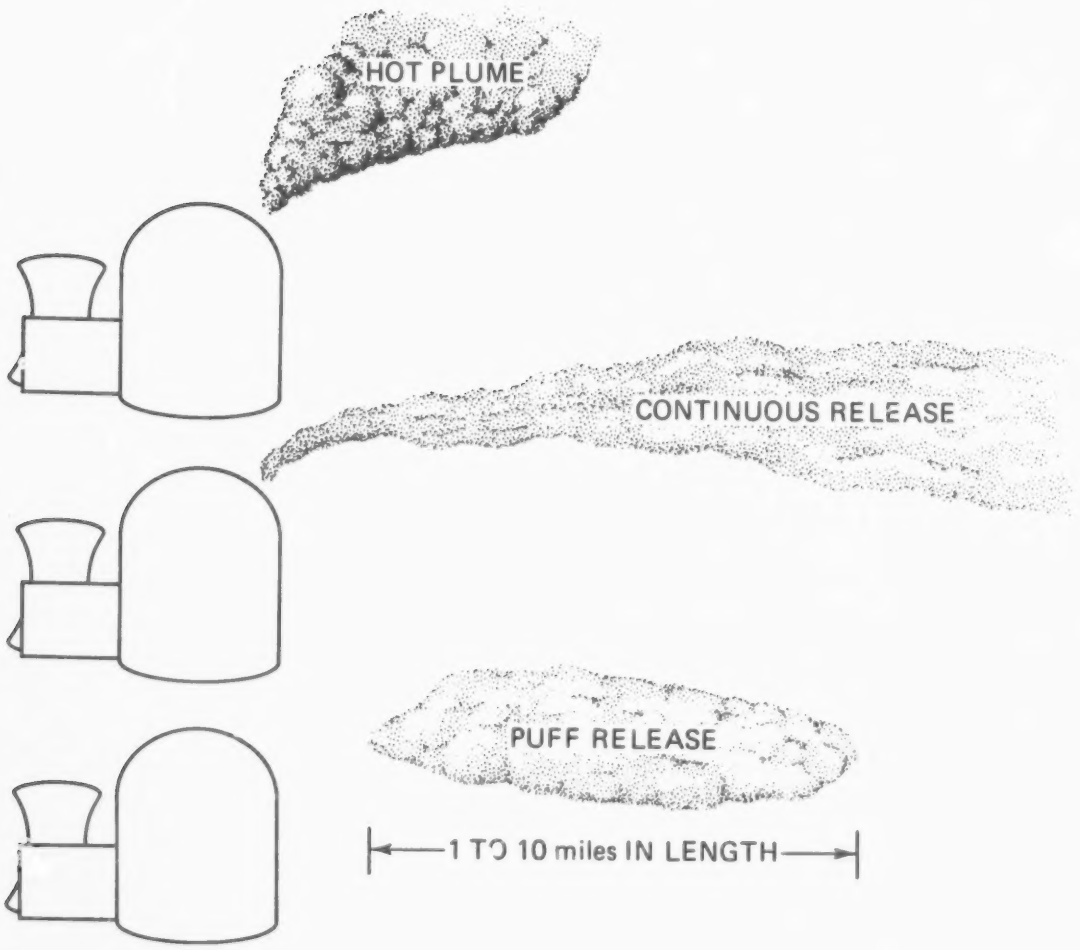
EXAMPLES OF PLUME TYPES



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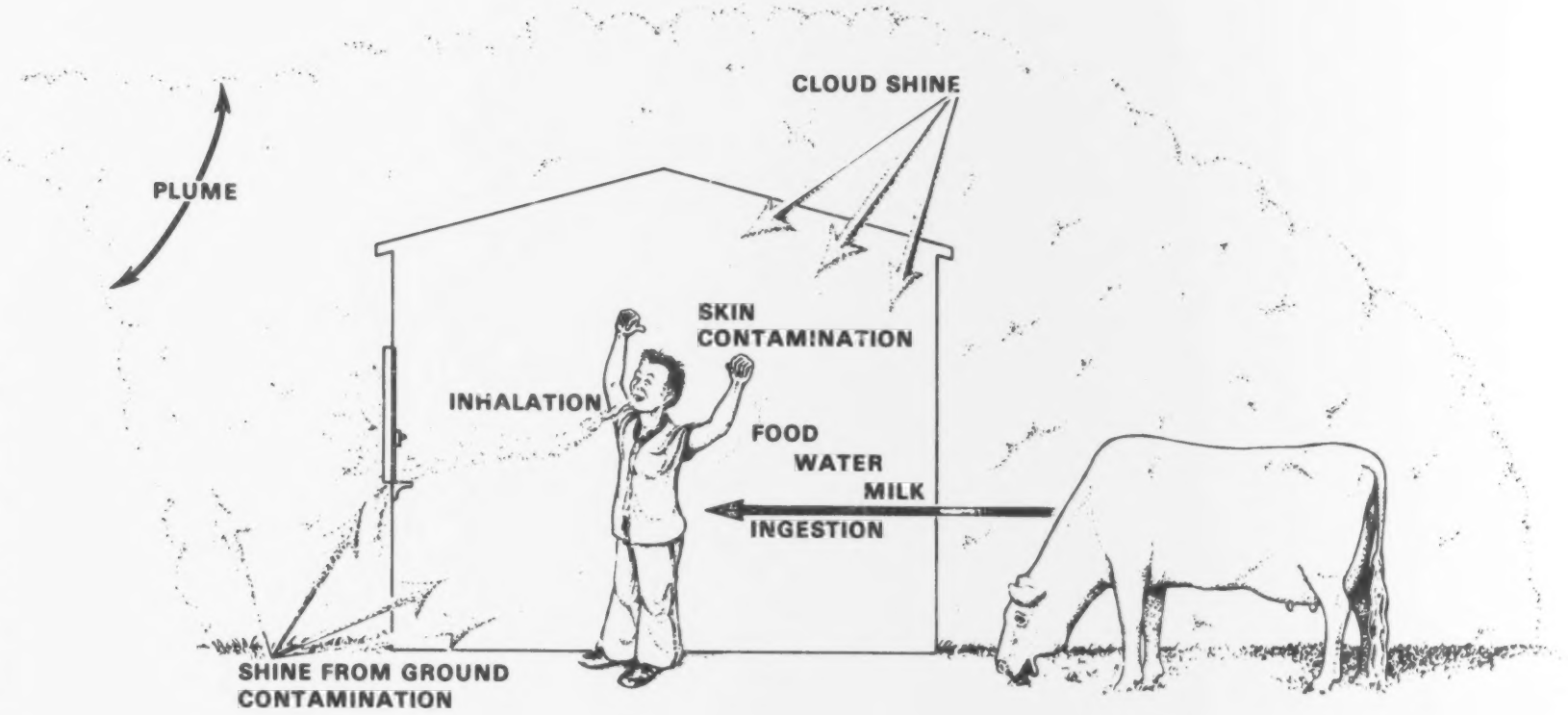
RADIATION DOSE PATHWAYS



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PROTECTIVE ACTION CRITERIA

Organ	Source of Dose	Consequences of High Dose
Whole body	Cloud shine Ground shine Inhalation	Death Injuries
Thyroid	Inhalation Ingestion	Injuries

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BASIC RADIATION PROTECTION OBJECTIVES

- *Avoid* or prevent early health effects doses
  - Injuries > 100 rem whole body
  - Deaths > 200 rem whole body
- *Reduce* doses above EPA and HHS PAGs
  - Whole body > 0.5 rem
  - Thyroid > 1.5 rem
- *Control* long-term health effects — cancers
  - No minimum dose level

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EPA AND FDA PAGs

Organ	EPA PAGs for Plume Exposure (rem)	FDA PAGs for Food and Agricultural Products (rem)
Whole body (bone)	1–5	0.5–5
Thyroid	5–25	1.5–15
Other body organs	1–5	0.5–5

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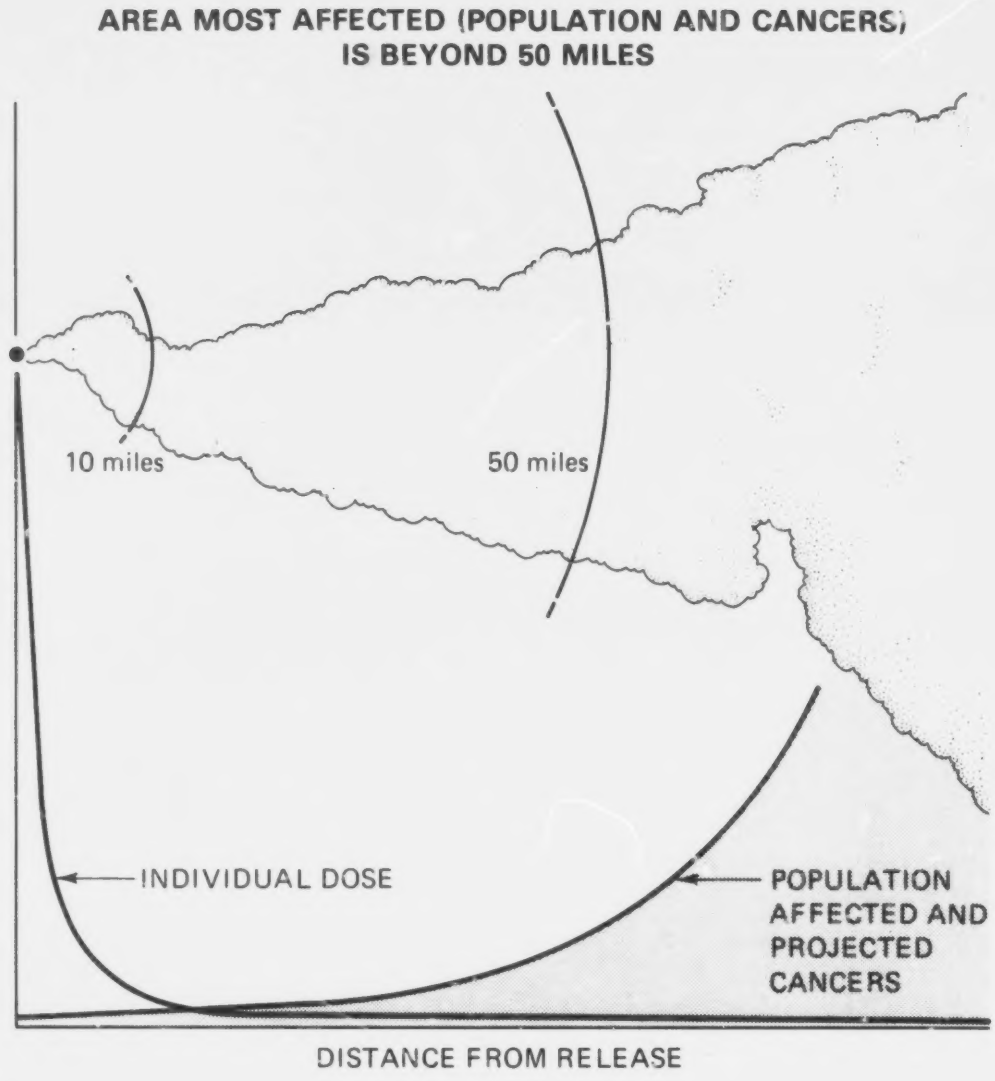

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SEVERE ACCIDENT EXAMPLE
(PWR 4)

- Major release
- Not largest possible
- Core melt
- Containment failure
- Reduction of iodine / cesium before release
  - Holdup
  - Containment spray
- Puff release (1 to 2 hr)

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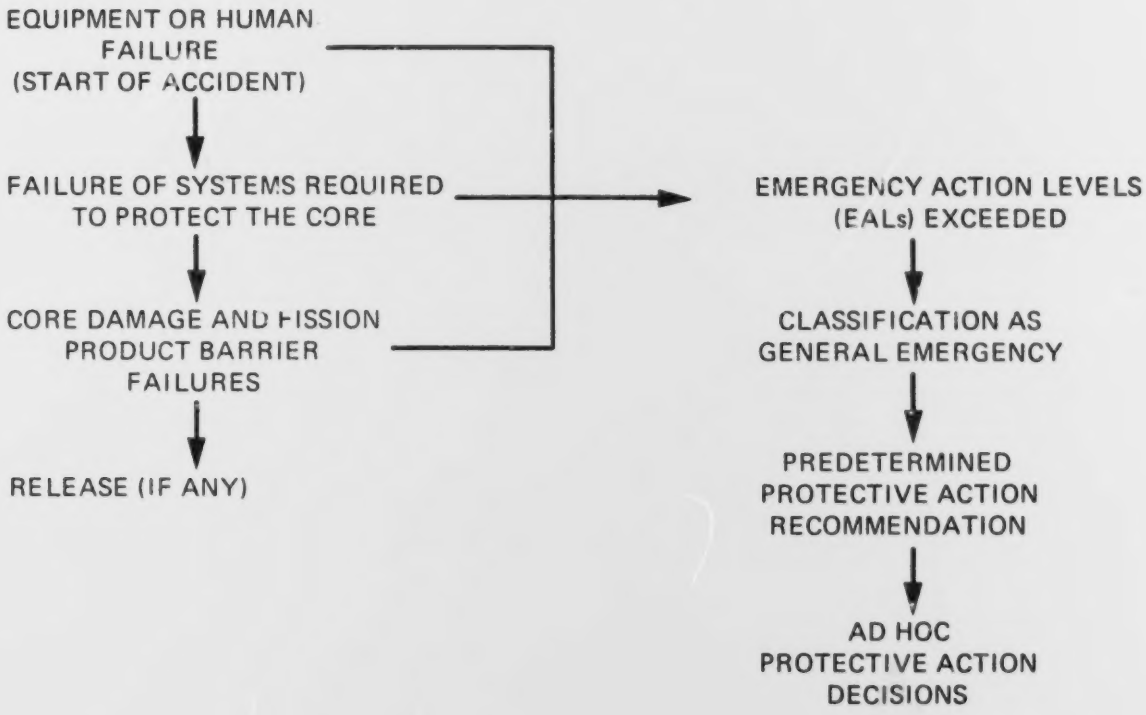
EALs ARE USED TO CLASSIFY ACCIDENTS AND RECOMMEND ACTIONS


EQUIPMENT OR HUMAN FAILURE (START OF ACCIDENT)
FAILURE OF SYSTEMS REQUIRED TO PROTECT THE CORE
CORE DAMAGE AND FISSION PRODUCT BARRIER FAILURES
RELEASE (IF ANY)
EMERGENCY ACTION LEVELS (EALs) EXCEEDED
CLASSIFICATION AS GENERAL EMERGENCY
PREDETERMINED PROTECTIVE ACTION RECOMMENDATION
AD HOC PROTECTIVE ACTION DECISIONS

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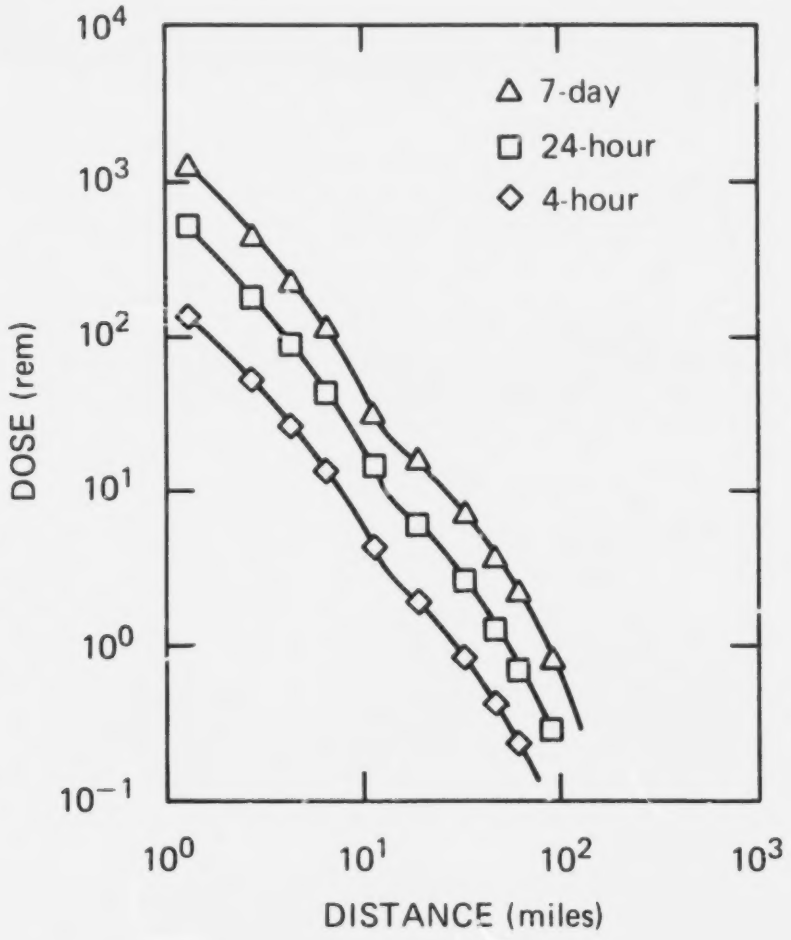
EXAMPLE FROM NUREG-1062, DOSE CALCULATIONS FOR SEVERE LWR ACCIDENT SCENARIOS

PWR #4
CASE 4

STABILITY CLASS: D
WIND SPEED: 6 mph

RAIN: NO
SHELTERING: NONE

WHOLE BODY DOSE



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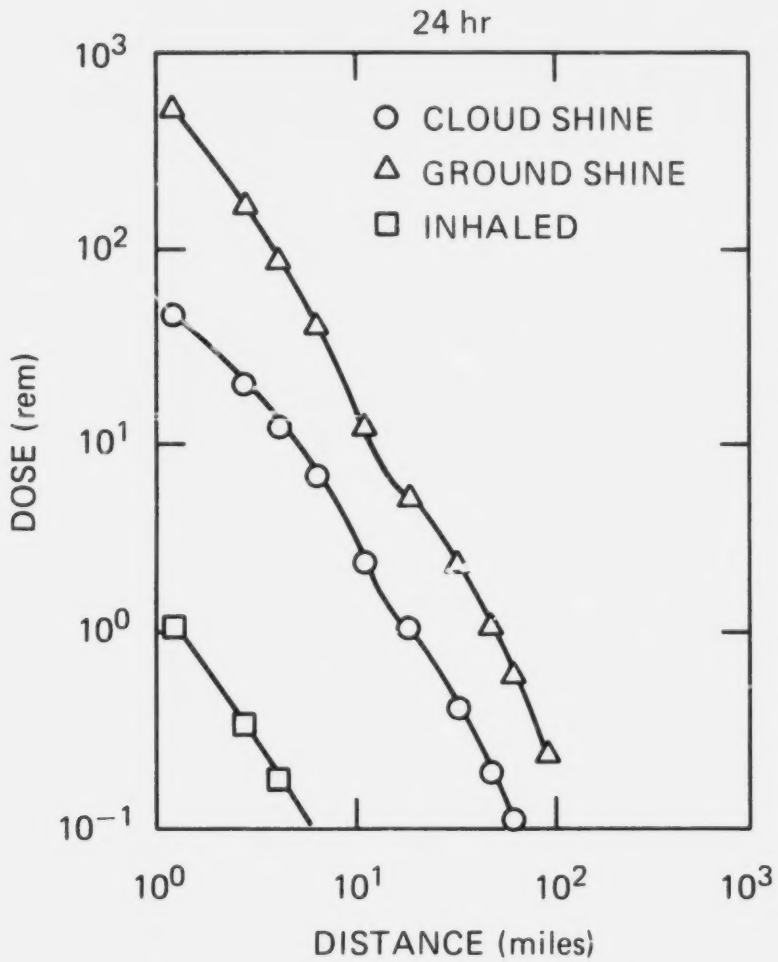
EXAMPLE FROM NUREG-1062, DOSE CALCULATIONS FOR SEVERE LWR ACCIDENT SCENARIOS

PWR #4
CASE 4

STABILITY CLASS: D
WIND SPEED: 6 mph

RAIN: NO
SHELTERING: NONE

WHOLE BODY DOSE



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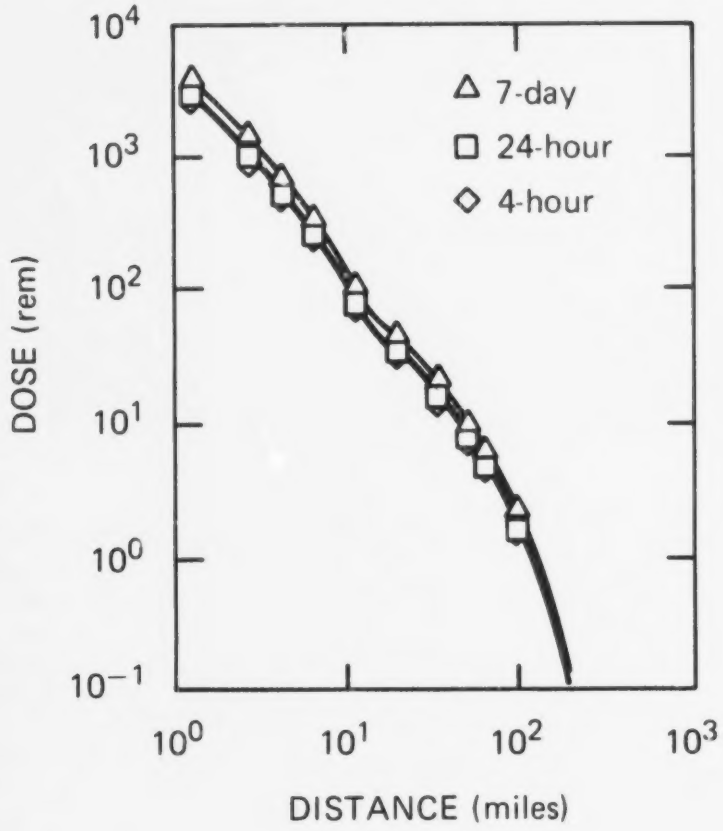
EXAMPLE FROM NUREG-1062, DOSE CALCULATIONS FOR SEVERE LWR ACCIDENT SCENARIOS

PWR #4
CASE 4

STABILITY CLASS: D
WIND SPEED: 6 mph

RAIN: NO
SHELTERING: NONE

THYROID DOSE



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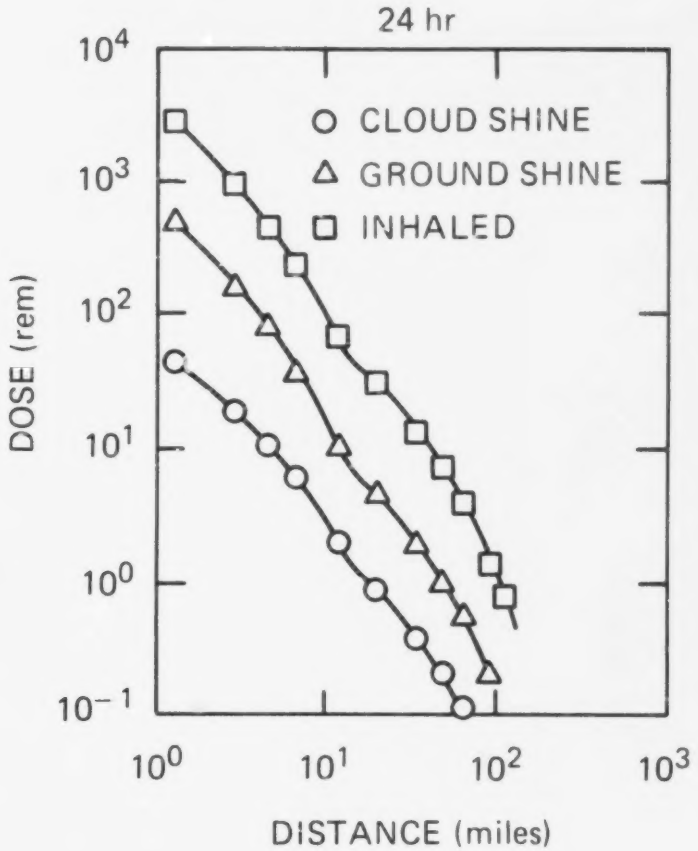
EXAMPLE FROM NUREG-1062, DOSE CALCULATIONS FOR SEVERE LWR ACCIDENT SCENARIOS

PWR #4
CASE 4

STABILITY CLASS: D
WIND SPEED: 6 mph

RAIN: NO
SHELTERING: NONE

THYROID DOSE



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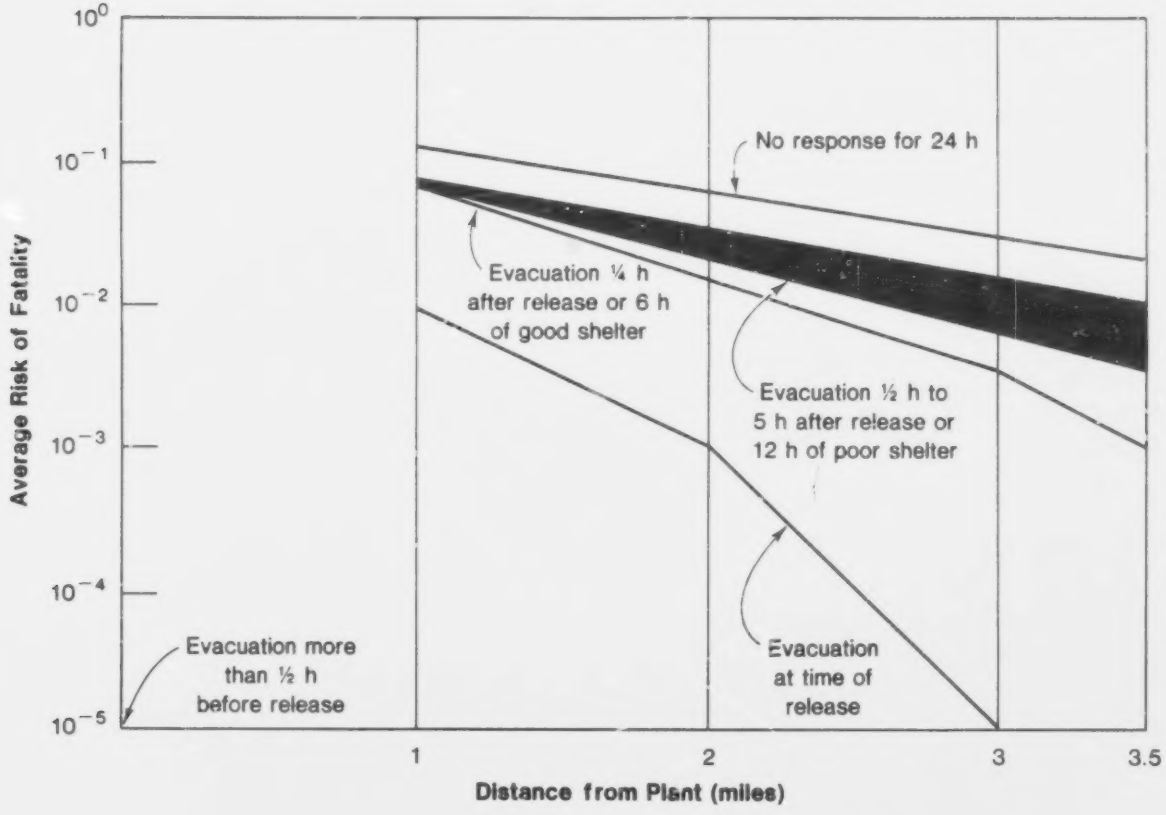
COMPARISON OF EVACUATION VS SHELTER FOR REDUCING EARLY FATALITY RISK FOR THE WORST ACCIDENT



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CONCLUSIONS OF WORST-ACCIDENT ANALYSIS

- Evacuation must begin before or shortly after a release to reduce risk
- Movement of short distances is effective
- Shelter near the plant for long periods is not effective

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INDEPENDENT OF RELEASE SIZE

- Greatest need for protective actions: 2 to 3 miles from plant
- Large release: actions to prevent early health effects
- Smaller release: actions to keep doses below PAGs

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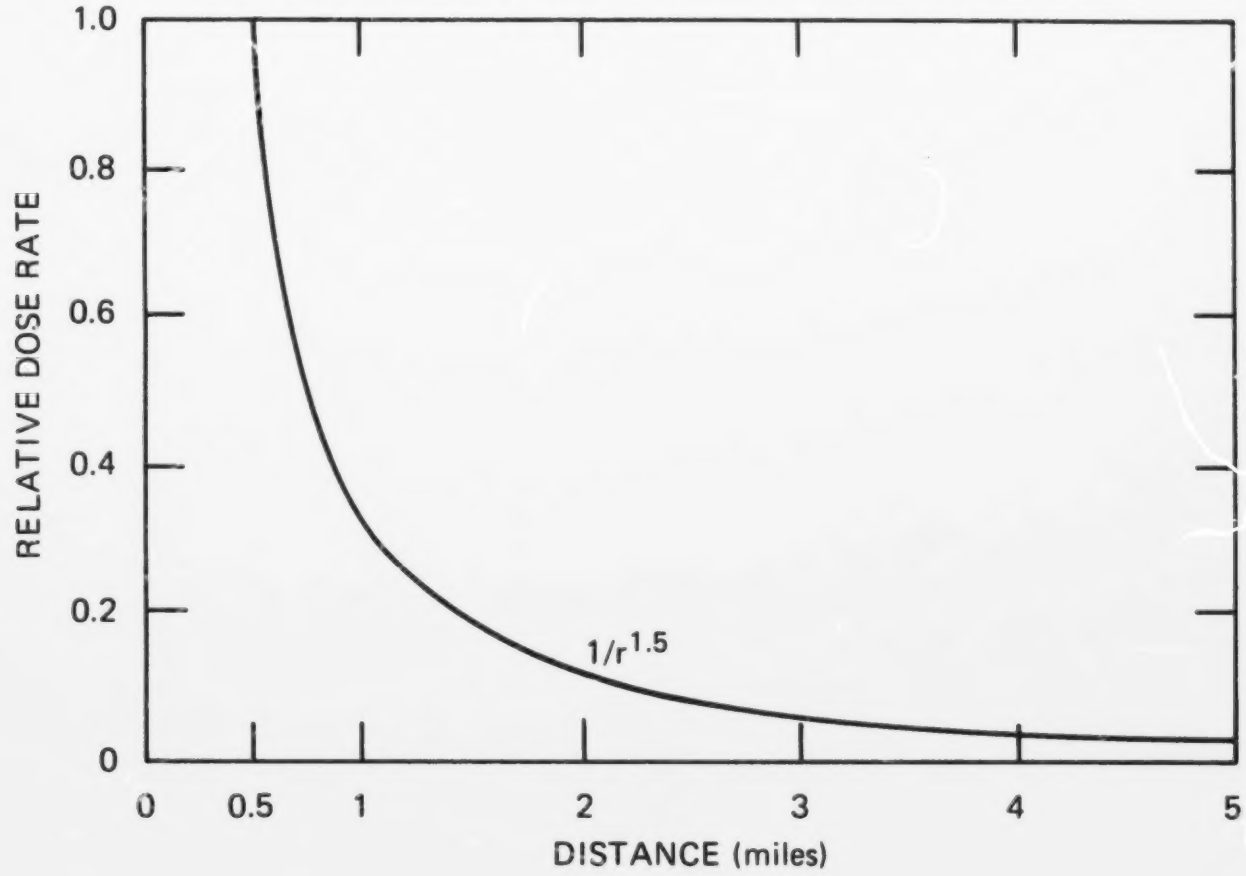
GENERAL RELATIONSHIP OF DOSE RATE AND DISTANCE FOR AN ATMOSPHERIC RELEASE



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POTENTIAL PUBLIC PROTECTIVE ACTIONS

- Evacuation
- Sheltering
- Improvised respiratory protection
- Use of thyroid-blocking agents for radioiodides (potassium iodide)

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EVACUATION

- For severe accidents, evacuation may be the only option to prevent early health effects
- Benefits of early evacuation
  - — *Avoid* shine dose from plume – or at least part of it
  - — *Avoid* shine dose from ground and other surfaces
  - — *Avoid* inhalation of contaminated air
  - — *High-risk areas are cleared early*
    - Relieves response teams of major decision-making tasks
    - Planners can direct more attention to those farther from plant
- Early evacuation not practical if entrapment is likely
  - — Major snow storm in progress
  - — All roads blocked
  - — Very high population density
  - — Special situations (surgery, jails holding dangerous prisoners)

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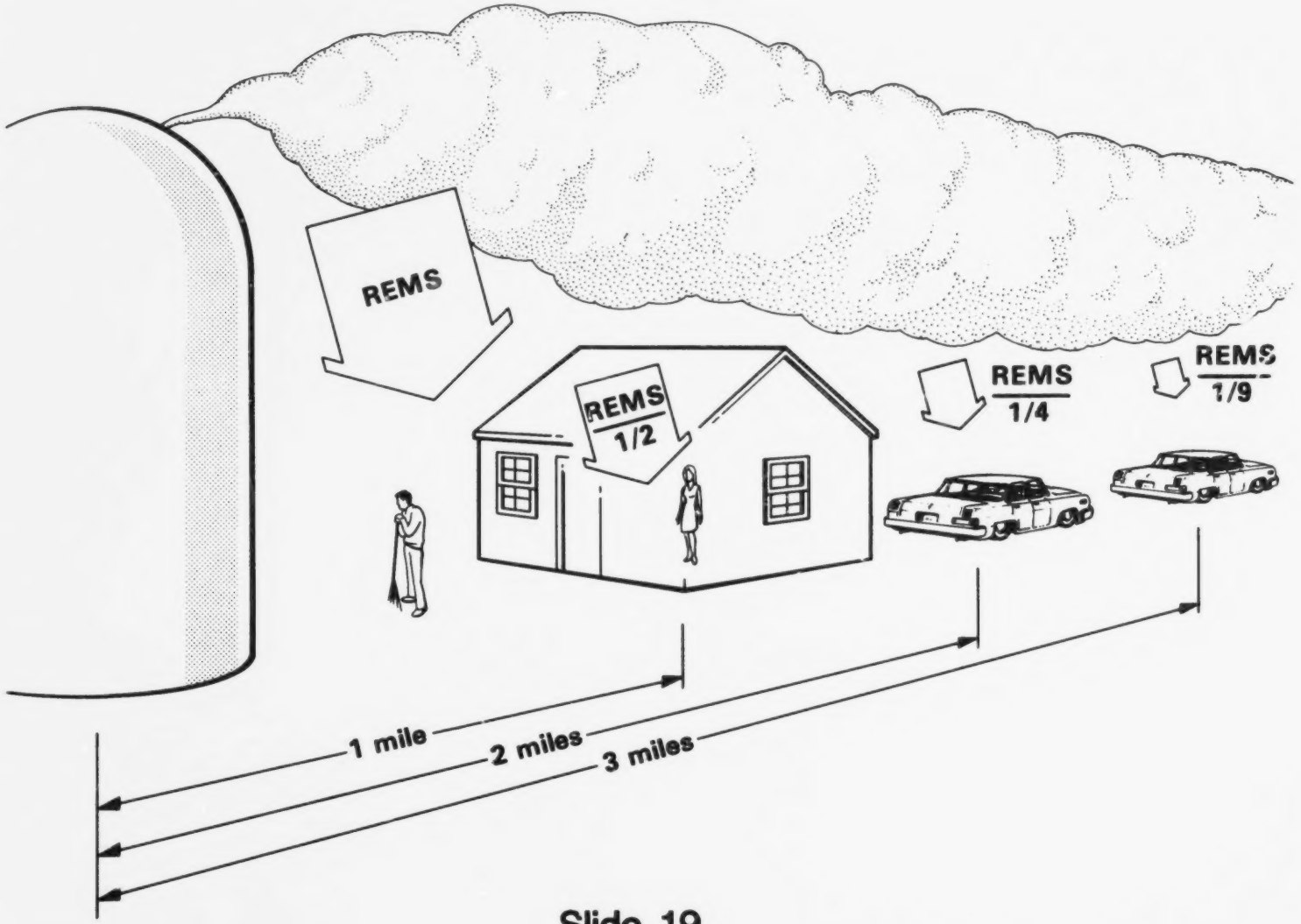
SHELTER VS DISTANCE IN REDUCING DOSE



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SHELTERING IS APPROPRIATE FOR

- Areas in which the risk of exceeding doses required for early health effects is relatively low
- Lesser events such as a site emergency
  - — Major release is not expected
  - — People should be ready to evacuate quickly if conditions deteriorate
- Instances where severe entrapment problems are likely to occur if early evacuation is attempted
- At very great distances

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DOSE REDUCTION FACTORS FOR VARIOUS SHELTERS (FOR COMPARISON ONLY)

Type of Shelter	Cloud Shine	Ground Shine	Inhalation Exposure
Small frame building			
Without basement	1	2	2
With basement	3	5 to 10	3
Multiple-story concrete structure	5	10	5

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IMPROVISED RESPIRATORY PROTECTION

- Improvised respiratory protection is a secondary protective action
  - May be recommended in conjunction with
    - Sheltering
    - Evacuation
  - Reduces inhalation exposure only (up to one-third of total whole-body dose)
  - Loose-fitting towel over nose and mouth reduces inhalation dose from particulates by factor of 2
  - Tight-fitting towel may reduce dose by factor of 10
  - No reduction for gas inhalation dose

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RESPIRATORY PROTECTION PROVIDED BY COMMON HOUSEHOLD AND PERSONAL ITEMS AGAINST PARTICLES

	Number of Thicknesses	Efficiency (%)
Toilet paper	3	91.4
Handkerchief, man's cotton	Crumpled	88.1
Bath towel, turkish	1	73.9
Bed sheet, muslin	1	72.0
Handkerchief, man's cotton	1	27.5

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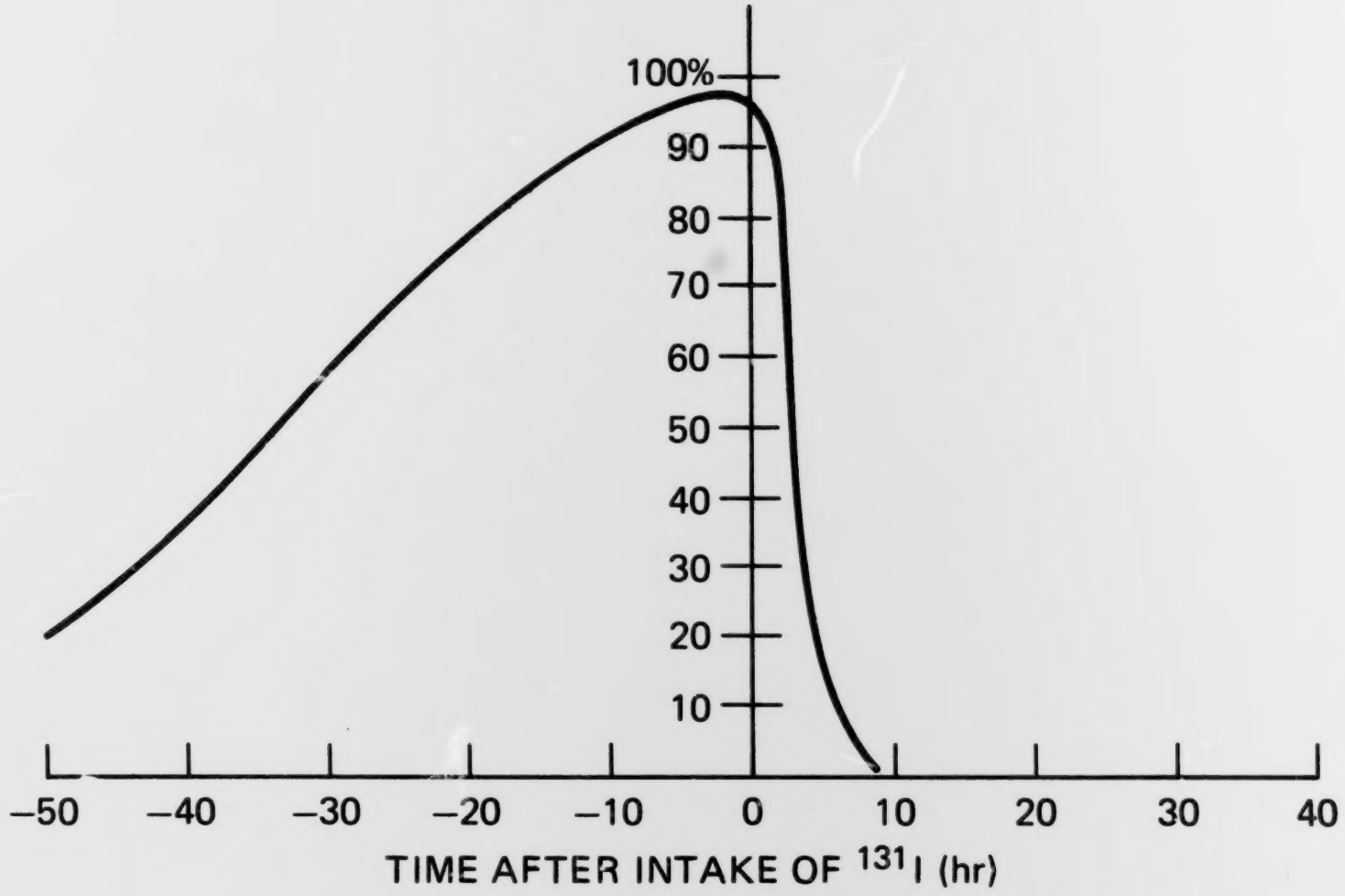
PERCENT OF THYROID BLOCKING AFFORDED BY 100 mg OF IODINE (130 mg OF KI)



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USE OF KI

- Reduces only thyroid dose resulting from radioactive iodine
- It is *not* an adequate substitute for evacuation or other protective actions
- For a major accident, thyroid dose is *not* the primary source of risk
- KI is recommended by NRC for
  - Emergency workers
  - Site personnel
  - Individuals who cannot evacuate promptly
- KI must be promptly available to be potentially effective

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WHY PROTECTIVE ACTIONS SHOULD NOT BE RECOMMENDED FOR ONLY THE DOWNWIND DIRECTION NEAR THE PLANT

- It would be impossible to predict downwind direction when
  - Release takes place
  - Evacuation starts
- Greatest risk is near the plant

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BASES FOR PROTECTIVE ACTION

- To exceed EPA PAGs, a release must occur from
  - Reactor coolant system
  - Spent fuel storage pool
- Releases resulting in early health effects can occur only as a result of
  - Severe core damage
  - Early containment failure
- Predicting containment performance is difficult

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MOST EFFECTIVE PROTECTIVE ACTIONS FOR SEVERE REACTOR ACCIDENTS

- Actions taken before or immediately upon release
- Evacuation near the plant (2 to 3 miles) and shelter out to about 10 miles
- After the release, evacuation of "hot spots"
- Protective actions may be required beyond 10 miles

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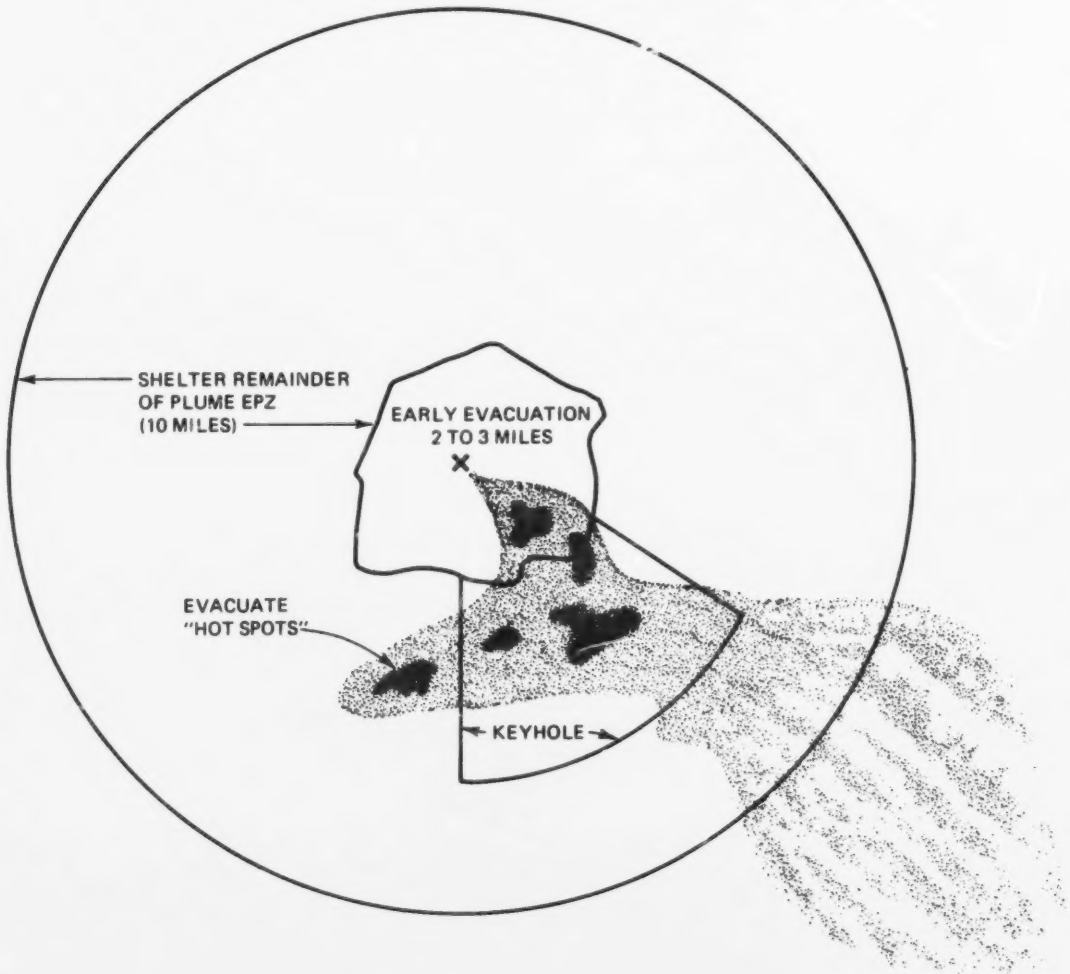
EARLY PROTECTIVE ACTIONS FOR CORE MELT ACCIDENTS



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BASIC PROTECTIVE ACTION OBJECTIVES OF THE SEVERE (CORE DAMAGE) ACCIDENT STRATEGY

- *Avoid* early health effects
  - Take actions before the release on the basis of plant conditions
  - Evacuate near the plant for a core melt
  - Evacuate "hot spots"
- *Reduce* dose above PAGs
  - Adjust initial actions for PAGs

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NRC SEVERE ACCIDENT GUIDANCE

- Take action before the release based on plant conditions
- For core damage, evacuate for 2 to 5 miles in all directions and shelter elsewhere
- Don't evacuate in the event of a controlled release (venting) before possible evacuation
- Evacuate "hot spots"

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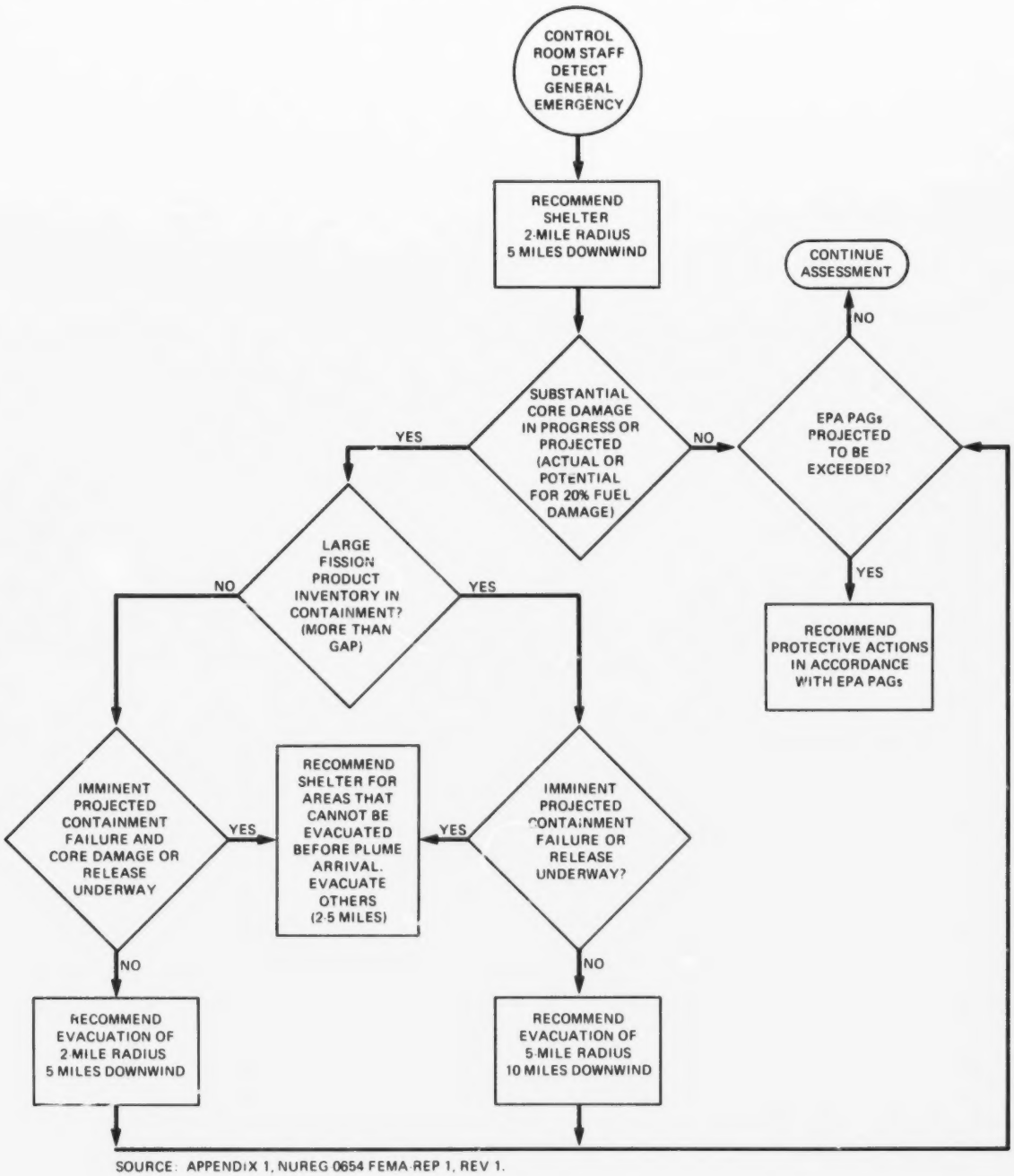
FLOW CHART FOR GENERAL EMERGENCY OFFSITE PROTECTIVE DECISIONS


CONTROL ROOM STAFF DETECT GENERAL EMERGENCY
RECOMMEND SHELTER 2-MILE RADIUS 5 MILES DOWNWIND
SUBSTANTIAL CORE DAMAGE IN PROGRESS OR PROJECTED (ACTUAL OR POTENTIAL FOR 20% FUEL DAMAGE)
YES
NO
EPA PAGs PROJECTED TO BE EXCEEDED?
NO
CONTINUE ASSESSMENT
YES
RECOMMEND PROTECTIVE ACTIONS IN ACCORDANCE WITH EPA PAGs
LARGE FISSION PRODUCT INVENTORY IN CONTAINMENT? (MORE THAN GAP)
NO
YES
IMMINENT PROJECTED CONTAINMENT FAILURE AND CORE DAMAGE OR RELEASE UNDERWAY
YES
RECOMMEND SHELTER FOR AREAS THAT CANNOT BE EVACUATED BEFORE PLUME ARRIVAL. EVACUATE OTHERS (2-5 MILES)
YES
IMMINENT PROJECTED CONTAINMENT FAILURE OR RELEASE UNDERWAY?
NO
NO
RECOMMEND EVACUATION OF 2 MILE RADIUS 5 MILES DOWNWIND
RECOMMEND EVACUATION OF 5-MILE RADIUS 10 MILES DOWNWIND

SOURCE: APPENDIX 1, NUREG 0654 FEMA-REP 1, REV 1.

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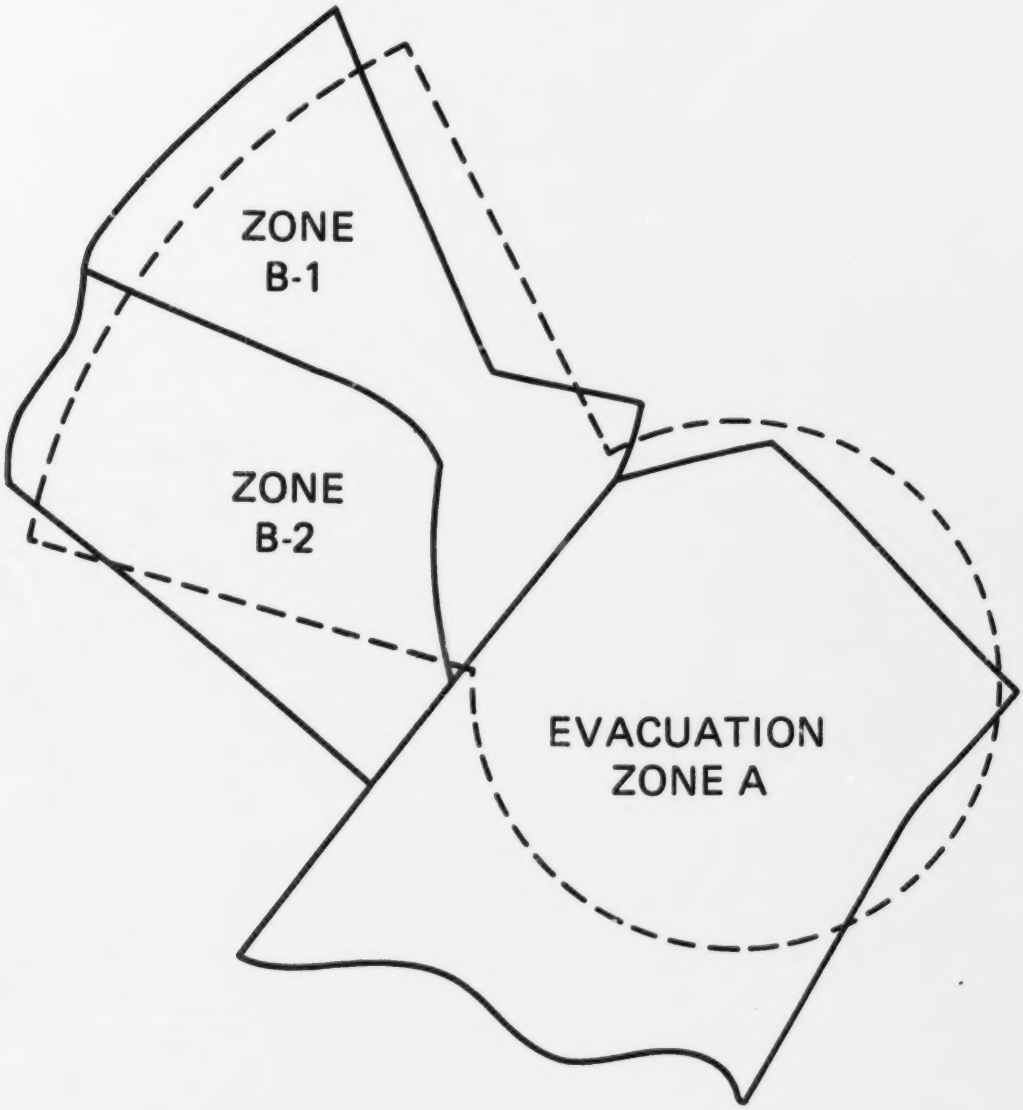
TYPICAL KEYHOLE



("DOWNWIND" HAS MEANING ONLY
DURING A RELEASE, NOT BEFORE)

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PUFF RELEASES

- Unpredictable
  - Bypass
  - Explosions
  - Isolation failures
  - Overpressurization
    - 2 to 3 times design pressure
    - Takes hours (time to evacuate)
- Predictable
  - Venting to mitigate accident

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DOSE PROJECTIONS

- Adjust initial protective actions
  - — Accerding to EPA PAGs
- Give way to field monitoring

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EPA RECOMMENDED PROTECTIVE ACTIONS

Projected Dose (Rems)		Recommended Actions for the Population
Whole Body	Thyroid	
<1	<5	No planned actions Monitor the environment
1 to <5	5 to <25	Shelter, as a minimum Consider evacuation Monitor the environment Control access
5 and above	25 and above	Mandatory evacuation Monitor the environment Control access

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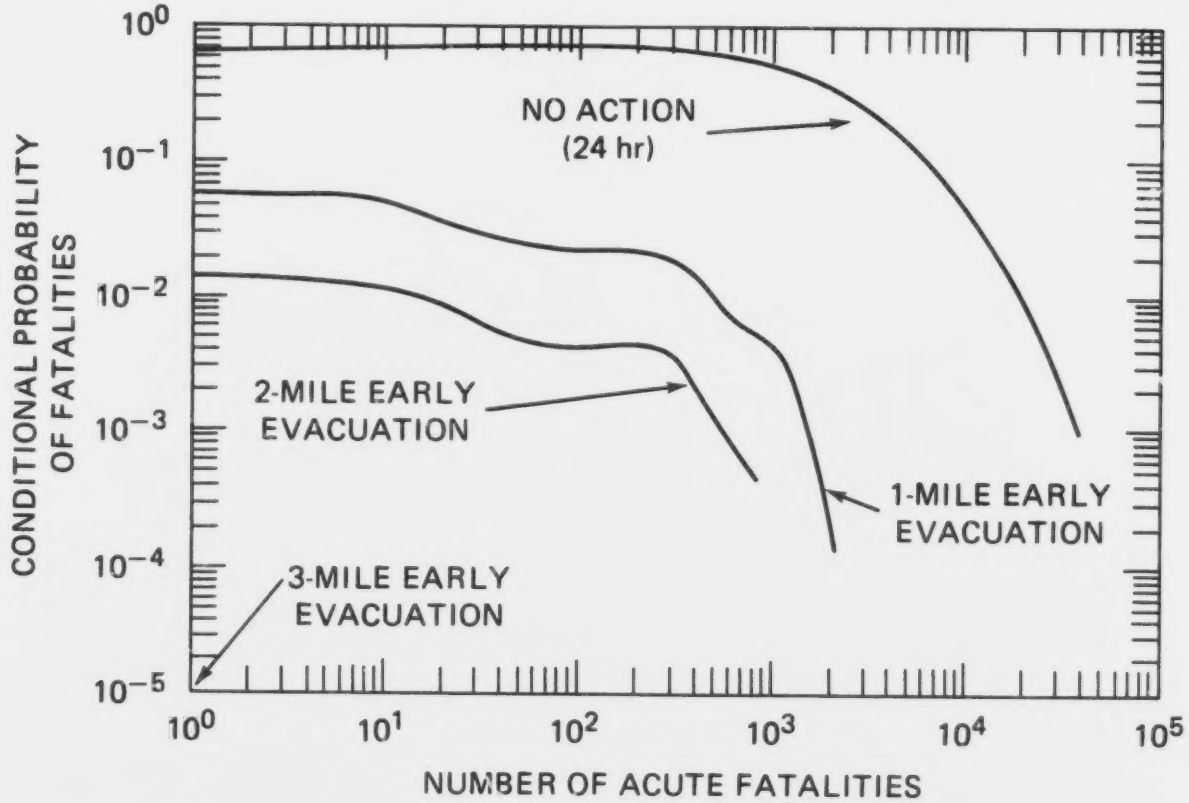
PROBABILITIES OF FATALITIES, ASSUMING LARGEST REACTOR ACCIDENT AND EARLY EVACUATION



NOTE: LARGE UNCERTAINTIES

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CONCLUSION

- Virtually all early fatalities can be prevented for the worst possible accident if
  - — Area near the plant is evacuated before or very shortly after the release, followed by
  - — Prompt monitoring (within 4 hr) to locate "hot" spots requiring further evacuation

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ENTRAPMENT IS POSSIBLE BECAUSE OF SUCH EVENTS AS SNOW AND EARTHQUAKE

- Local officials will make decisions based on local conditions
- Best shelter or evacuation possible
- Emergency plans do not guarantee protection under all conceivable circumstances

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EXAMPLES OF LARGE-SCALE EVACUATIONS (6 MONTHS IN 1978)

Date	Number of People Evacuated	Place	Incident
6/30/78	3,000	Destrehan, LA	Rail car gas leak (styrene gas)
6/21/78	600,000	Salonika, Greece	Earthquake
5/15/78	1,000	Nacogdoches, TX	Chemical explosion; train wreck
4/26/78	1,500	Bowling Green, KY	Tank car containing poisonous gas ruptured
4/8/78	1,500	Brownson, NB	30-car derailment; tank car exploded (phosphorous)
4/6/78	2,000	Pineville, KY	Liquid propane tank car leak
4/1/78	2,500	Kingsburg, IN	Chemical plant fire; toxic fumes
3/15/78	2,000	Steubenville, OH	Chemical plant explosion; toxic chlorine fumes
3/8/78	1,200	Vicksburg, MS	Insecticide tank at chemical plant exploded
3/2/78	200	Galax, VA	1,600-gal liquified propane spill
2/27/78	250	Youngstown, FL	Ruptured railway car; chlorine gas; wind shift noted
2/27/78	2,000	Waverly, TN	Derailed tank car explosion; volatile propane
1/28/78	500	Damascus, AR	Leak from fuel tank (NO_4)
1/17/78	52	Pond Eddy, PA	11,000-gal acetaldehyde spill

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RADIOLOGICAL RISK VS EVACUATION RISK

- Historical fatality risk for evacuation is about 1 in 500,000
- Estimated fatality risk for core melt accident is roughly 1 in 10 to 1 in 100
- Less risk to leave the vicinity of a core melt accident early
- For a typical reactor site, population within a 1- to 5-mile radius is much less than 10,000, so fatality risk is very low for evacuations within this distance

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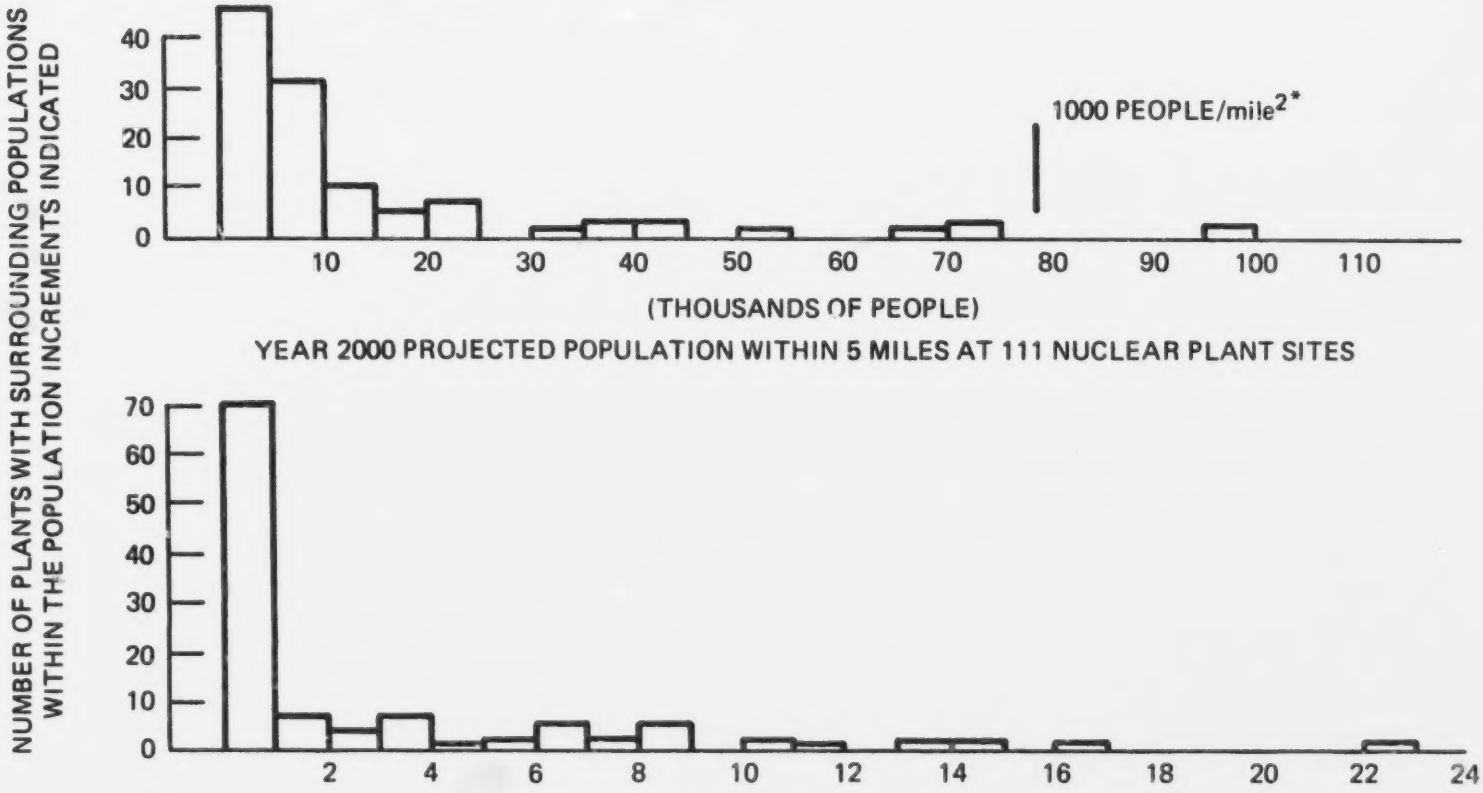
NUMBER OF PEOPLE WITHIN 1 AND 5 MILES OF 111 NUCLEAR POWER PLANTS, ACTUAL OR PROPOSED IN 1979



*1000 PEOPLE/mile^2 (DURING LIFETIME GUIDELINE) VALUE USED; ALL SITE POPULATION DATA NORMALIZED TO YEAR 2000 BY ESTIMATING PROJECTED POPULATION INCREASES.

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WOULD EVACUATION BEHAVIOR BE DIFFERENT IF THE THREAT WERE RADIATION?

- No reason exists to suspect that people will react differently than they would for a flood, fire, etc.
- Risk of injury or death due to a nuclear-related evacuation should not be any higher than for other types of emergencies

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RESPONSE OF PEOPLE TO EVACUATION

- Widespread panic uncommon and spotty; may be nonexistent
- Disaster victims react with initiative
- Some people insist on acting on their own
- Local organizations have generally been able to cope with emergencies
- Most disasters have not led to antisocial behavior (e.g., looting)
- Disasters do not destroy community morale
- Some people will not follow recommendations
- Most people react calmly and normally to authoritative directions

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KEYS TO A SUCCESSFUL PUBLIC EMERGENCY RESPONSE

- Early warning
- Clear instructions
- Provided by recognized authority figures
  - — Police, firefighters, mayor
  - — Broadcast news media

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NRC NOT PART OF EARLY PROTECTIVE ACTION DECISION PROCESS

- NRC response organization not available for an hour or more
- NRC does not know plant as well as licensee or off-site officials
- Early protective actions must be implemented without a call to the NRC first

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MAJOR POINTS

- Protective actions are not warranted for less than core melt accidents
- For core melt accidents, protective actions must be planned to be taken based on plant EALs, preferably *before a release*. Projected dose is secondary
- Under most conditions, if core melt is indicated, people near the plant should be notified and motivated to leave immediately where at all possible
- For core melt accidents, protective actions near the plant should be taken in all directions
- For severe accidental releases to the atmosphere, the major threat is from the passing cloud, but ground contamination may dominate the dose in a few hours, especially where such releases intercept rainfall

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MAJOR POINTS (Continued)

- At exceedingly low probability levels, protective action may be required even beyond 10 miles
- Although core damage will be easy to detect, the future course of such an accident and containment response will be difficult to predict during a severe accident
- The predetermined evacuation / shelter / relocation protective action scheme for a General Emergency can be demonstrated to provide significant risk reduction potential

Slide 47 (Continued)

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MAJOR POINTS (Continued)

- In the event of a core melt accident, off-site officials should implement early, initial protective actions without calling the NRC first
- Evacuations are not uncommon
- Evacuations by up to a few thousand people have historically been a low-risk activity
- Most people will react calmly and normally during an emergency evacuation
- An evacuation order should not be delayed for fear of panic

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Slide 47 (Continued)

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This is one in a series of volumes that collectively provide for the U.S. Nuclear Regulatory Commission (NRC) emergency response personnel the necessary background information for an adequate response to severe reactor accidents. The volumes in the series are:

- Volume 1 -- Overview and Summary of Major Points
- Volume 2 -- Severe Reactor Accident Overview
- Volume 3 -- Response of Licensee and State and Local Officials
- Volume 4 -- Public Protective Actions -- Predetermined Criteria and Initial Actions
- Volume 5 -- U.S. Nuclear Regulatory Commission Response

Each volume serves, respectively, as the text for a course of instruction in a series of courses for NRC response personnel. These materials do not provide guidance or license requirements for NRC licensees or state or local response organizations. Each volume is accompanied by an appendix of slides that can be used to present this material. The slides are called out in the text.

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